JUNE 1959

Journal

VOL. 51 • NO. 6

AMERICAN WATER WORKS ASSOCIATION

Coming up in San Francisco: AWWA's 79th Annual Conference July 12–17

In this issue:

UTILITY COSTS AND REVENUES
Howson

UTILITY NEEDS
Faust

'WATER CONDITIONER' CLAIMS
FTC Decision

JOINT WATER AND SEWAGE ADMINISTRATION
Committee Report

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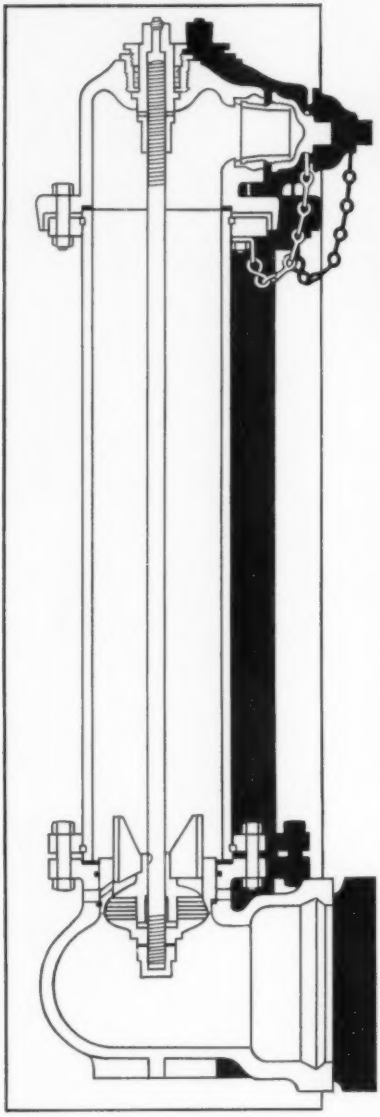
STANDARD FOR SODIUM ALUMINATE
AWWA B405



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Journal

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San Francisco, Calif. Jul. 12–17, 1959

Official reservation forms have been mailed to all members and are returnable to AWWA.

Coming Meetings

AWWA SECTIONS

Fall 1959

Sep. 8–10—Rocky Mountain Section, at Jackson Lake Lodge, Moran, Wyo. Secretary, V. A. Vaseen, 833—23rd St., Denver 2, Colo.

Sep. 9–11—Canadian Section, Maritime Branch, at White Point Beach Lodge, Liverpool, N.S. Secretary, J. D. Kline, Gen. Mgr., Public Service Com., Halifax, N.S.

Sep. 9–11—Wisconsin Section, at Hotel Schroeder, Milwaukee. Secretary, Harry Breimeister, Chief Utilities Engr., City Engineer's Office, City Hall, Milwaukee.

Sep. 14–16—Kentucky-Tennessee Section, at Lafayette Hotel, Lexington, Ky. Secretary, J. Wiley Finney Jr., Howard K. Bell, Cons. Engrs., 553 S. Limestone St., Lexington, Ky.

Sep. 16–18—New York Section, at Saranac Inn, Upper Saranac Lake. Secretary, Kimball Blanchard, Neptune Meter Co., New York Branch Sales Office, 2222 Jackson Ave., Long Island City.

Sep. 16–18—North Central Section, at Pick-Nicollet Hotel, Minneapolis, Minn. Secretary, L. N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Sep. 23–25—Michigan Section, at Bancroft Hotel, Saginaw. Secretary, T. L. Vander Velde, Chief, Section of Water Supply, State Dept. of Health, DeWitt Rd., Lansing.

Sep. 27–29—Missouri Section, at President Hotel, Kansas City. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Building, Jefferson City.

Oct. 7–9—Chesapeake Section at Sheraton-Belvedere Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Oct. 8–9—Intermountain Section, Pocatello, Idaho. Secretary, W. C. Hague, Chief Engr., Metropolitan Water Dist., 703 Tribune Bldg., Salt Lake City, Utah.

Oct. 14–16—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

(Continued on page 10)

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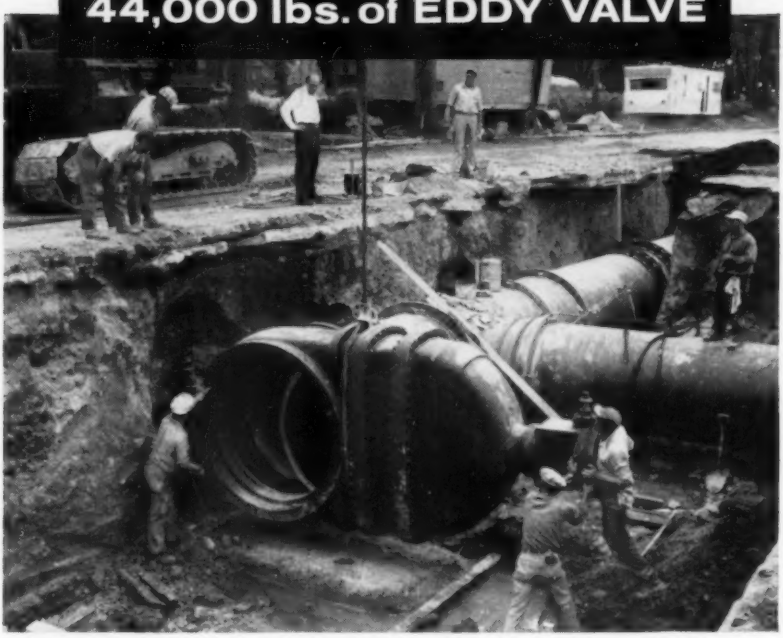

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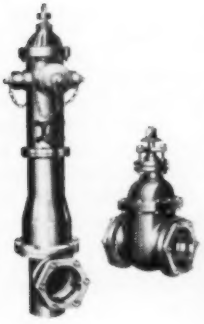

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Coming Meetings

(Continued from page 8)

Oct. 18–21—Alabama-Mississippi Section (with Southwest Section) at Roosevelt Hotel, New Orleans, La. Secretary, Ernest Bryan, Southern Sales Mgr., McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 18–21—Southwest Section (with Alabama-Mississippi Section) at Roosevelt Hotel, New Orleans, La. Secretary, L. A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 22–24—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 28–29—West Virginia Section, at Chancellor Hotel, Parkersburg. Secretary, Hugh W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

Oct. 28–30—Ohio Section, at Biltmore Hotel, Dayton. Secretary, J. Howard Bass, Robt. F. McGivern & Assocs., 1771 W. 5th Ave., Columbus.

Oct. 30—California Section (Business Meeting) at Hacienda Hotel, Bakersfield. Secretary, Roy E. Dodson Jr., Supt. of Production, San Diego Water Dept., Balboa Park, San Diego.

Nov. 4–6—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, E. H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond.

Nov. 9–11—North Carolina Section, at Washington Duke Hotel, Durham. Secretary, D. Y. Brannock, Director, Utilities Dept., Burlington.

Nov. 15–19—Florida Section, at Hillsboro Hotel, Tampa. Secretary, J. G. Simmons, Plant Supt., West Palm Beach Water Dept., Box 1311, West Palm Beach.

Dec. 3–5—Cuban Section, Havana. Secretary, Juan Berasategui, Civ. Engr., Calle K, No. 303, Apdo. 22, Vedado, Havana.

OTHER ORGANIZATIONS

Jul. 20–Aug. 14—USPHS Summer Training Institute short courses, to be given at Western Massachusetts Public Health Center on campus of University of Massachusetts, Amherst Mass.: Jul. 20–31—Basic Radiological Health; Jul. 27–Aug. 7—Aquatic Biology for Engineers; Aug. 10–14—Bioassay & Pollution Ecology. Write: Sylvan C. Martin, Regional Engr., Region II, Rm. 1200, 42 Broadway, New York 4, N.Y.

Jul. 22–25—International Conference on Waste Disposal in Marine Environment, under multiple sponsorship, University of California, Berkeley, Calif. Write: Dept. of Conferences, University Extension, Univ. of California, Berkeley 4, Calif.

Aug. 17–21—Short course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Sep. 7–11—Ion-Exchange Conference, sponsored by Oak Ridge National Lab., at Gatlinburg, Tenn. (attendance limited). Write: Prof. William Rieman III, Vice-Chairman, Ion-Exchange Conference, R. G. Wright Lab., Rutgers State University, New Brunswick, N.J.

Sep. 13–18—American Chemical Society, Atlantic City, N.J.

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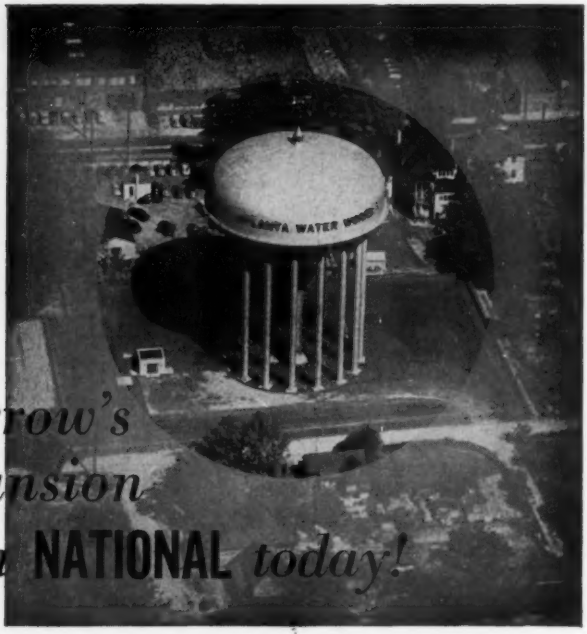

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333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafi., Lima, Peru

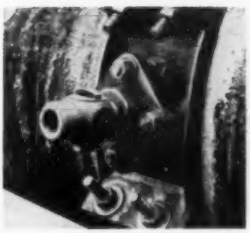
Tapping Water Lines Under Pressure

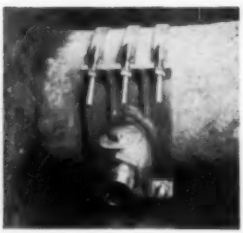
American Concrete Cylinder Pipe can be tapped with ease and economy while still under pressure.

The sudden explosive growth of many communities in the west has made it difficult for the best of advance planners to achieve both economy and adequate service in water supply systems designed for the future.

The possibility of unpredictable requirements for service outlets was one of the factors taken into consideration in the design of American Concrete Cylinder Pipe. Without de-watering the pipeline, small or large diameter outlets can be easily installed by any water works service group using standard tapping equipment. New outlying areas which mushroom in the typical western growth pattern can be readily integrated into a planned System if American Concrete Cylinder Pipe is used for the transmission lines.

CONCRETE PIPE FOR MAIN WATER SUPPLY LINES, STORM AND SANITARY SEWERS, SUBAQUEOUS LINES





American PIPE AND CONSTRUCTION CO.

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HAYWARD: P. O. Box 630 — JEfferson 7-2072
SAN DIEGO: P. O. Box 13 — CYpress 6-6166
PORTLAND: 518 N. E. Columbia Blvd.— BUtler 5-2531
ALBUQUERQUE: P. O. Box 1782 — CHapel 7-0486
PHOENIX: American Concrete Pipe Co. (Subsidiary)
P.O. Box 12127 — Alpine 2-7566

Engineering PLUS...

Keeps Tank Interiors Corrosion Free at a Practical Cost

One of the five municipal tanks serving the City of Jacksonville, Fla. which has been cathodically protected by E.R.P. system since 1942.

The City of Jacksonville, Fla. has relied on engineering plus from Electro Rust-Proofing Corp. since 1942 to protect water storage tanks serving the city. Since installation of cathodic protection, tanks have been virtually corrosion free on the under water surfaces and maintenance costs have been reduced to a minimum.

E.R.P. engineering plus means cathodic protection systems
designed to meet your needs...
maintained to your benefit...
priced to your profit...

E.R.P. provides engineering plus to meet any corrosion problem of submerged or buried metals. For full information on cathodic protection for your water storage tanks, water treatment structures and pipelines, write for bulletin E-42.05.

ERP CATHODIC PROTECTION SINCE 1935

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A SUBSIDIARY OF WALLACE & TIERNAN INC.
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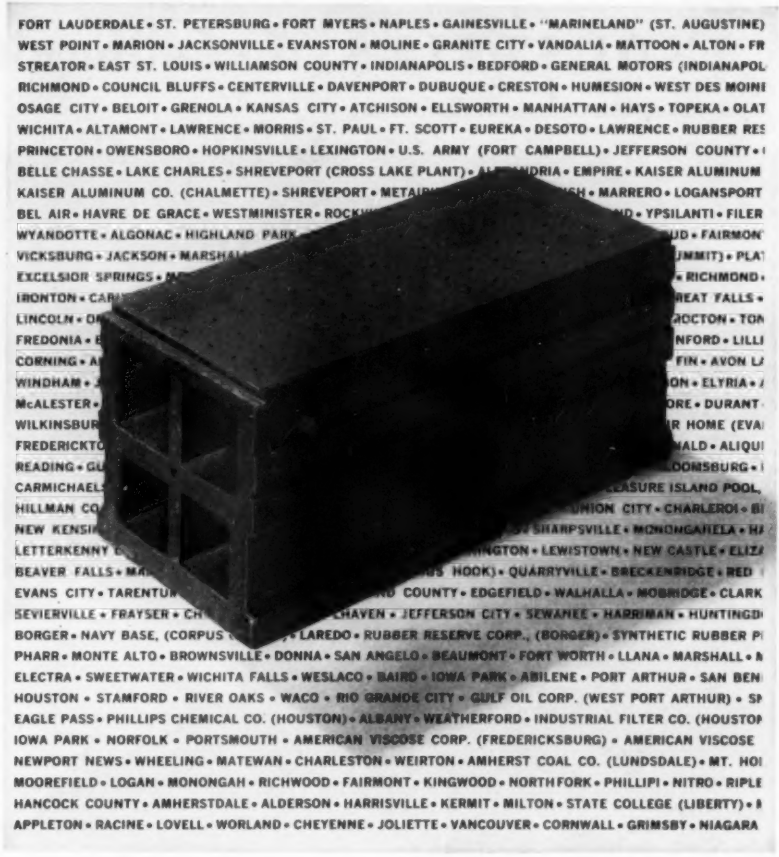
CABLE: ELECTRO, NEWARK, N. J.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The best way is to install Leopold Glazed Tile Filter Bottoms, just as all these plants have done.

Like them, you'll find Leopold Bottoms successfully meet all underdrain requirements. The individual Leopold blocks can't corrode or absorb water . . . are acid and alkali resistant . . . are not subject to tuberculation . . . and provide equal filtration and uniform wash distribution. In addition, because Leopold Bottoms won't wear out and assure minimum media maintenance, they are the most economical in the long run.

We'll be glad to supply facts and figures without obligation.

**Including over 100 rehabilitation projects*

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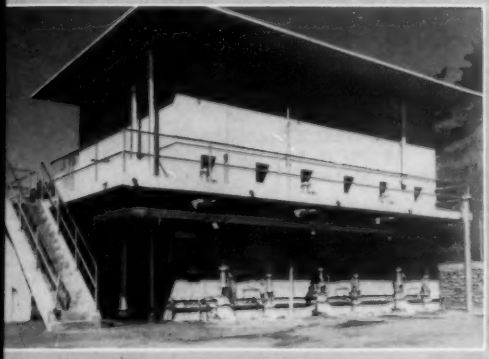
In California

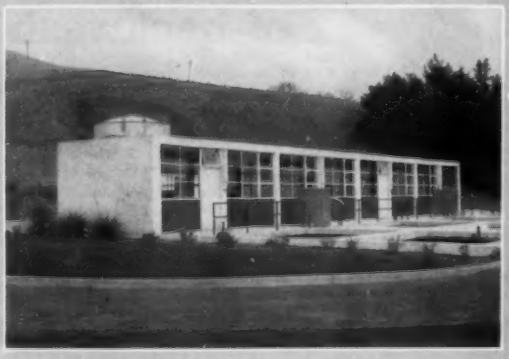
San Diego, California — Alvarado Water Treatment Plant

Antioch Water Treatment Plant

City of San Buena Ventura, California Water Treatment Plant



East Bay Municipal Utility District — LaFayette, California
Water Treatment Plant



POSITIVE CONTROL OF *MATERIALS IN MOTION* BIF METERS FEEDERS CONTROLS

. . . as across the country . . .

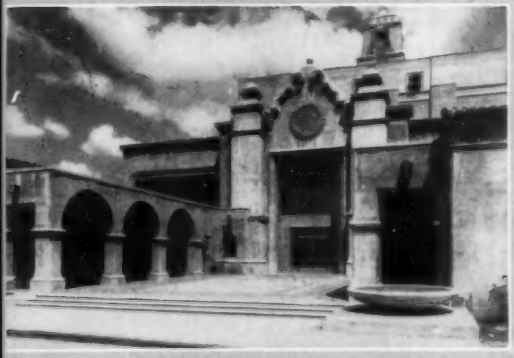
ONE SOURCE – ONE RESPONSIBILITY pays off!

One Source – One Responsibility results in better coordination of efforts during the planning, installation, start-up and operating stages of new or expanded facilities. Complete integration of all control equipment delivers maximum efficiency, operation economy and system reliability. B-I-F Industries is your single responsible source of control equipment for water works.

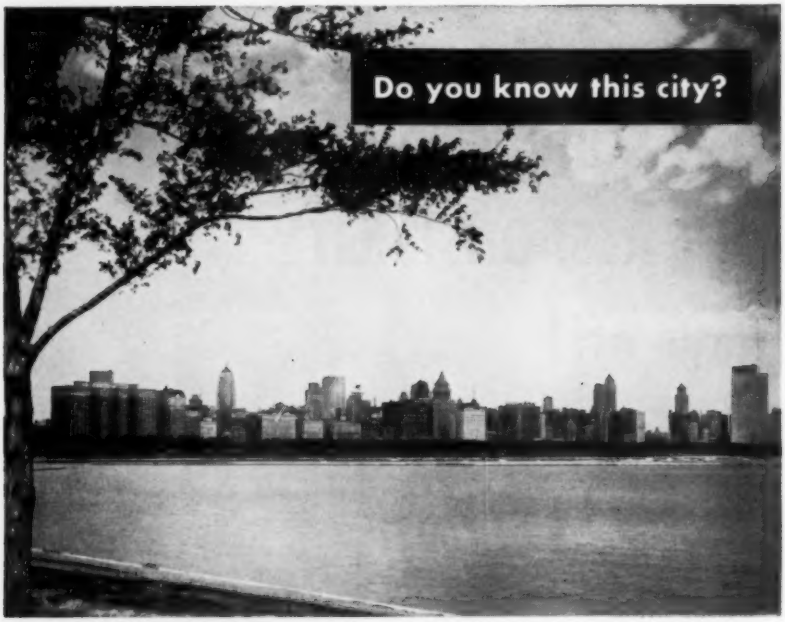
These California water works plants are typical of many in which B-I-F equipment is installed. The stars on the map are representative of California communities in which B-I-F equipment operates continuously . . . dependably. Ask a B-I-F man to show you one of these installations. Remember . . . no other manufacturer offers you such a broad range of performance-proven water works equipment.

Nationwide Sales and Service through local offices help maintain the high performance standards for which B-I-F is known. If you want complete satisfaction from your water works installation, write **B-I-F Industries, Utilities Sales, 365 Harris Ave., Providence 1, R. I.**

Metropolitan Water District of Southern California — La Verne (Los Angeles), California Water Treatment Plant



City of Hawthorne, California Water Treatment Plant



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maintain vital water requirements of...

Chicago...capital of the industrial midwest. This vast metropolis depends on De Laval centrifugal pumps to help maintain its high standards of public service. De Laval equipment has been on the job in Chicago for nearly 50 years...a remarkable record of dependability. Today, in fact, the great majority of American cities use De Laval centrifugal pumps. Their design and manufacture are the result of more than 57 years of experience. Units ranging up to 100 million gallons per day are available to meet all water works requirements.

Write for your copies of DeLaval Bulletins 1004 and 1005 giving data on these pumps

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DE LAVAL STEAM TURBINE COMPANY

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"DO IT NOW!"

but make sure you don't have to do it again!

Specify Permanent **CAST IRON PIPE** *for Water and Sewer Mains*

Appeal of the AWWA to American communities to "Do It Now" in speeding up improvements of water systems brought good results in 1958. This year many more communities are launching water works and sewer improvement and expansion programs to provide for increased future water needs.

AWWA National Survey Shows:

- **Twenty per cent of the systems are deficient in supplies of available water . . .**
- **Forty per cent need more transmission facilities . . .**
- **Thirty per cent are short of pumping capacity . . .**
- **Forty per cent require greater treatment capacities and better treatment methods . . .**
- **Thirty per cent are deficient in ground storage capacities . . .**
- **Forty per cent need more elevated distribution storage . . .**
- **Sixty per cent must provide bigger and better distribution systems.**

When your community develops its water system, make sure you don't have to "do it again" 10 or 15 years from now.

Only permanent Cast Iron Pipe can provide this assurance. Its record of long life—a century or more—and its minimum maintenance cost have never been matched by any other pipe ever made. That's why it has long been known as "America's No. 1 Tax Saver."

Our Company does not manufacture pipe, but supplies the nation's leading Cast Iron Pipe manufacturers with quality iron from which quality pipe is made.

WOODWARD IRON COMPANY
Since 1882
WOODWARD, ALABAMA

New! BADGER Read-o-Matic* REGISTER

adds speed-reading to water metering

Here is the industry's first practical outdoor register — the Badger Read-o-Matic. Now meter reading routes can be completed in half the time — with no more wasted calls. Plus other important benefits such as:

• ***No more "lockouts"*** • ***No more in-house accidents*** • ***No more access problems*** • ***No more inconvenienced customers***

The new Badger Read-o-Matic means a modern meter reading system that your water department can have now — and opens a whole new realm of possibilities for the future. You'll want to read about them in our free new Badger Read-o-Matic folder.

*Pat. applied for in U. S. A. and foreign countries

Here's the big news behind the industry's first practical outdoor register

The Badger Read-o-Matic is powered entirely by the meter to which it is attached . . . works on an exclusive "pulse" principle. As water flows through the meter, the generator sends a pulse by wire to the Badger Read-o-Matic register outside for accurate recording.

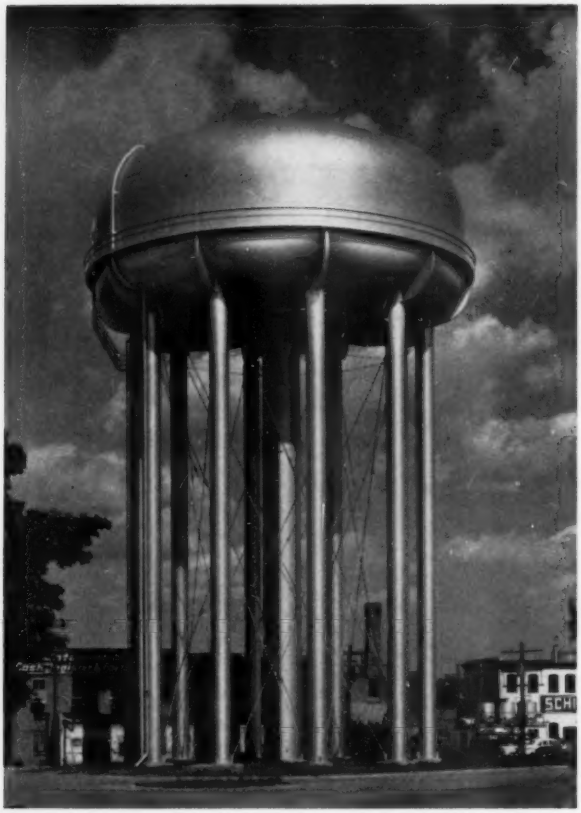
Like our Badger meters, the Badger Read-o-Matic is precision-engineered — thoroughly tested by our trained water meter experts in the laboratory and in the field. Badger Meter products are the result of over 50 years of *specialized* water meter experience — products that excel around the world in accuracy, durability, dependability and low maintenance cost.

Send for free, colorful brochure that tells you all about the revolutionary Badger Read-o-Matic. For an actual demonstration, see your Badger representative or write us direct.

Badger Water Meters

Badger Meter Mfg. Co. • 4545 W. Brown Deer Rd. • Milwaukee 18, Wis.

Minimum Water Pressure Raised From 5 to 40 Pounds In Mt. Prospect, Illinois



1,000,000-Gallon Radial Cone Elevated Tank and Reservoir Aid Water Pressure

A shortage of water and low water pressure was overcome in the constantly expanding village of Mt. Prospect, Illinois, as a result of an improvement program including the erection of a Horton radial cone elevated tank and a steel reservoir, each with a capacity of 1,000,000 gallons. The radial cone tank has a 30-foot head range and a height to bottom capacity of 95 feet. The steel reservoir has a diameter of 73 feet and a height of 32 feet. As a result of these improvements, minimum water pressure was raised from 5 to 40 pounds.

Write to our nearest office for an estimate or information.

Chicago Bridge & Iron Company

Plants in Birmingham, Chicago, Salt Lake City, New Castle, Del. and Greenville, Pa.

ATLANTA	DETROIT	NEW YORK	SAN FRANCISCO
BIRMINGHAM	HOUSTON	PHILADELPHIA	SEATTLE
BOSTON	KANSAS CITY, MO.	PITTSBURGH	SOUTH PASADENA
CHICAGO	NEW ORLEANS	SALT LAKE CITY	TULSA
CLEVELAND			

In Canada—HORTON STEEL WORKS, LIMITED, FORT ERIE, ONT.

NOW...

cut new filtration plant costs 45%

Increase clear water capacity 100%

Specify Celite diatomite filtration

You can now double the potable water capacity available to your growing community and cut the installation cost of new filtration nearly in half. How? Specify diatomite filtration. You'll reduce land and construction costs because diatomite systems need only ¼ the housing space of equivalent-capacity sand plants. In fact diatomite systems are so compact, they can sometimes be added to existing plants.

If you're considering water filtration for the first time, it makes good financial sense to go Celite* diatomite all the way. An actual test installation by Johns-Manville has proved that a diatomite filter station can be installed for 45% less than a sand filter station of equal capacity.†

What's more, Celite will usually give better water clarity under comparable conditions. Turbidity is far lower. More suspended solids, including all floc, amoebae and algae, are removed. And a Celite diatomite system is easily operated and maintained by regular municipal water personnel.

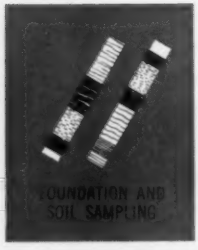
Mined from the world's purest commercially available deposit, Celite is carefully processed for complete uniformity. Call your nearby Celite engineer for complete information on Celite's wide range of grades; he will gladly assist with your particular problems. And write today for FREE informative reprint.† Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

†Comparison Studies of Diatomite and Sand Filtration by G. B. Bell, Journal American Water Works Association, September, 1956.

JOHNS-MANVILLE JM PRODUCTS

LAYNE-the only complete water service organization



COMPLETE SERVICE

MEANS UNDIVIDED RESPONSIBILITY

In an age of specialization there is a definite advantage in doing business with a company offering a COMPLETE SERVICE. Only Layne, with over 75 years of experience and backed by Layne Research, can offer its customers this complete water service.

Layne

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Visit our booth 55–58, AWWA Convention, San Francisco, July 12–17.

AMERICAN METERS

HAVE WHAT THE WATER SUPERINTENDENT WANTS

AMERICAN Meter with Sealed Metal Register Box.

EASY READING

- **WHITE FIGURES**
- **NON-FOG SEALED METAL REGISTER BOX**

Plain black figures on a pure white background make AMERICAN METERS easy to read, even in dark pits. When desired we can furnish a solid metal register box with heavy ¼ inch thick crystal-glass top. This sealed box is free from condensation or moisture and the crystal-glass is non-fogging.

Easy reading means fast, accurate reading so necessary to avoid complaints. Only AMERICAN METERS use crystal-glass, assuring perfect clarity without distortion.

Yes, the AMERICAN METER register face is the answer to the Water Superintendent's request for Easy Reading!

The easiest, fastest meter to read is AMERICAN.

BUFFALO METER COMPANY
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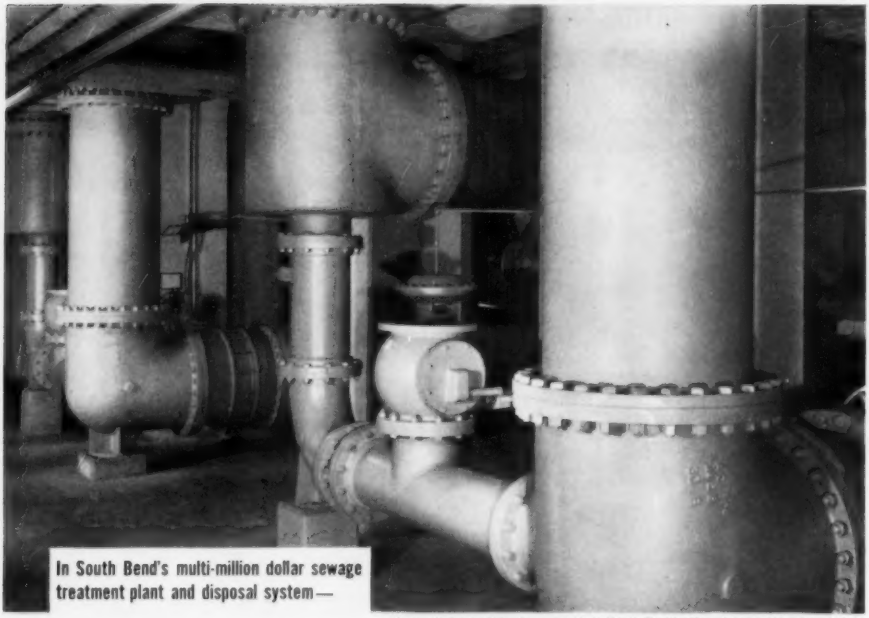

Large diameter American specials in South Bend's 48 mgd sewage treatment plant.

American Cast Iron Pipe and Fittings help solve a river pollution problem

A million pounds of American Cast Iron pipe and fittings were specified for South Bend, Indiana's, modern sewage treatment plant. Part of a long range sewage disposal improvement program, its completion has helped overcome a serious river pollution problem.

American Cast Iron pipe and fittings help overcome problems in many other areas as well. Where the need for long trouble-free service life must be met with economy, the proven strength, long life, corrosion resistance, and high flow capacity of American Cast Iron pipe provide the right answer.

In your new plant or system, as in South Bend and thousands of other sewage, water treatment, and industrial installations, American Cast Iron pipe, fittings and specials help solve today's most common problem—long range operational economy.

Call your nearby American Cast Iron Pipe Company representative for helpful facts while your new plant or addition is in the planning stage.

See Booths 81-82, Annual AWWA Conference
San Francisco, July 12-17

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CAST IRON PIPE CO.
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MORE THAN 2,000 PRESTRESSED CONCRETE WATER TANKS IN SERVICE

In the development of residential and industrial water supply facilities today, no other type of tank offers so many advantages as does the Prestressed Concrete Tank. Modern in engineering and design, proven in service, lowest in cost... prestressed concrete should be considered in any tank planning.

Check these advantages:

- Minimum maintenance
- Satisfied owners
- 75% of construction cost spent locally
- Lowest overall cost to community
- Longest service life of any tank

Send for Bulletin T-22

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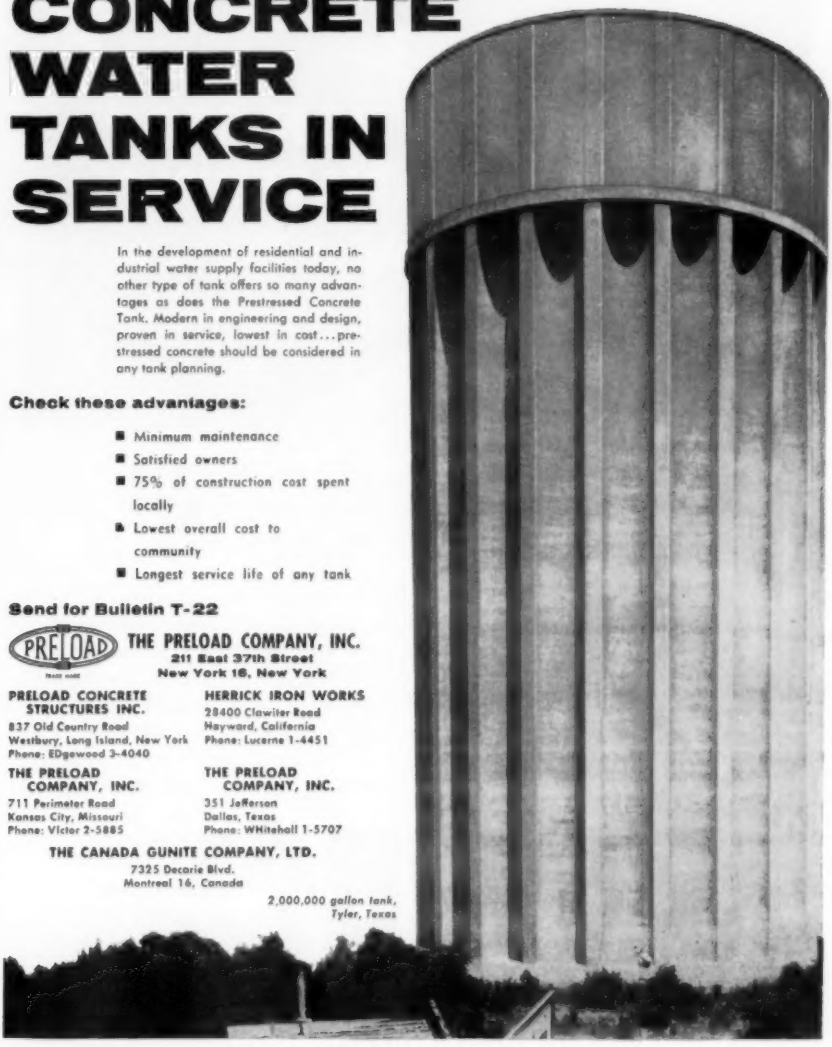


2,000,000 gallon tank, Tyler, Texas

NON-STOP FILTERING

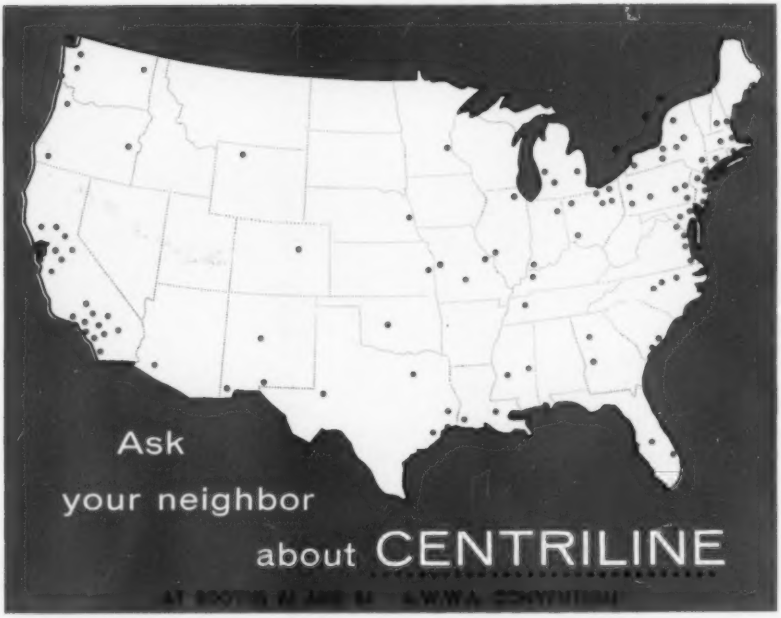
even when backwashing GFC Multi-Cell Filters

There's no time lost when backwashing GFC Multi-Cell Filters. While one cell is being backwashed, the other cells provide: **(a)** Water for backwashing that cell **with or without** the use of storage tanks or surface reservoirs. **(b)** Uninterrupted filtering to maintain a continuous flow to service lines. Other important features include low-cost installation and GFC's patented non-clogging "Multi-Plate" underdrains. Write for bulletins and equipment data.

GENERAL FILTER CO.

WATER PROCESS EQUIPMENT AMES, IOWA

AERATORS • FILTERS • SOFTENERS • CLARIFIERS
FLASH MIXERS • FLOCCULATORS • PNEUMATIC CONTROLS
ROTARY DISTRIBUTORS • SLUDGE SCRAPERS



Spotted on this map are some of the places that have been served by the Centriline Process

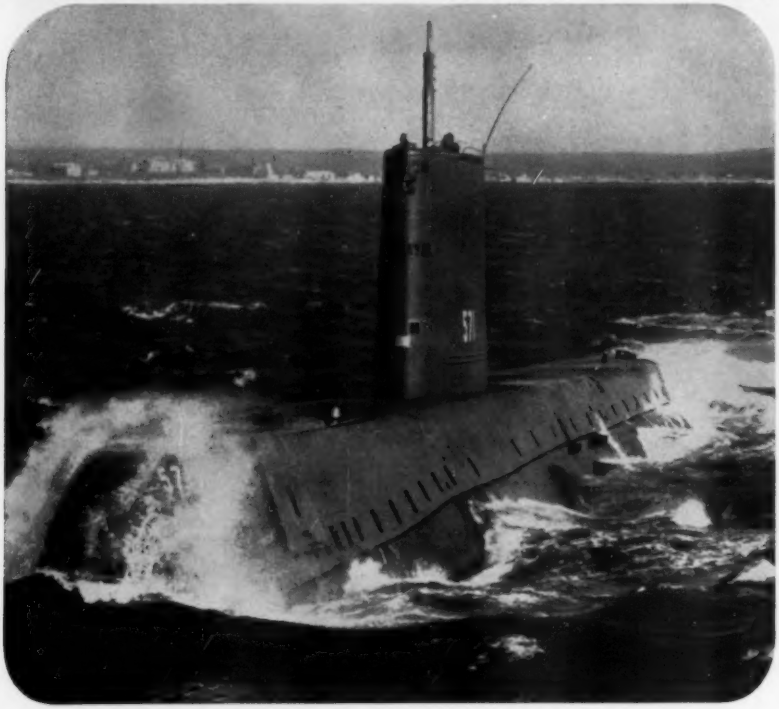
Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Now here's your chance to find out.

Briefly, this process smoothly lines piping—*in place*—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline. *Ask your neighbor.*

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help *you* solve the problems of pipe reconditioning in place.

CENTRILINE CORPORATION
A Subsidiary of Raymond International, Inc.
140 CEDAR STREET • NEW YORK 6, N. Y.
Branch offices in principal cities of the United States, Canada, and Latin America.

ION EXCHANGE RESINS serve the new atomic navy



In Atomic Powerplants on Nuclear-Powered Submarines, AMBERLITE Ion Exchange Resins Remove Radioactive Contaminants

Because water impurities become radioactive when exposed to radiation, cooling water which passes through reactors on Navy atomic submarines is treated by passage through beads of specially-developed, highly active grades of AMBERLITE Ion Exchange Resins. These resins remove all metallic ions from the water and also are used to control pH of coolant within safe limits. In addition, they have the important advantage of concentrating in small volume the radioactive materials which they remove from water.

These special cation and anion exchange resins for reactors are usually supplied in an intimate mixture for use in MONOBED units. Complete technical information on special Nuclear Grade AMBERLITE Ion Exchange Resins and their uses will be sent promptly on request. Consult your engineering company experienced in water conditioning on how AMBERLITE resins may serve you.

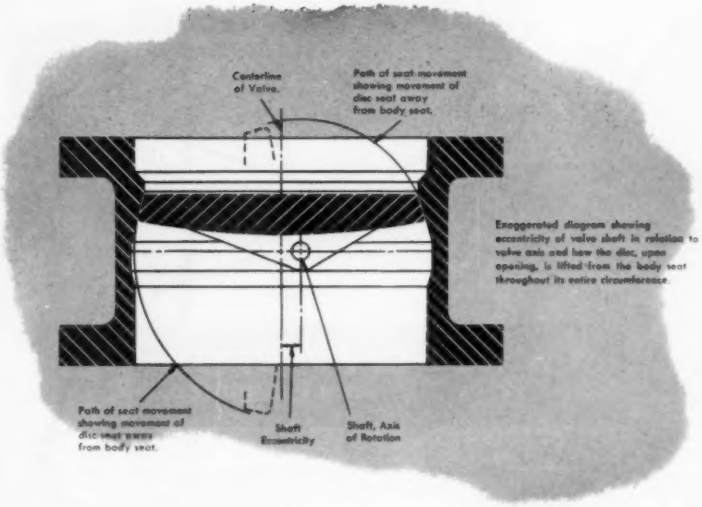
AMBERLITE and MONOBED are trademarks, Reg. U.S. Pat. Off. and in principal foreign countries.

Chemicals for Industry

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.


Centerline of Valve.
Path of seat movement showing movement of disc seat away from body seat.
Exaggerated diagram showing eccentricity of valve shaft in relation to valve axis and how the disc, upon opening, is lifted from the body seat throughout its entire circumference.
Path of seat movement showing movement of disc seat away from body seat.
Shaft Eccentricity
Shaft, Axis of Rotation

How **DARLING-PELTON BUTTERFLY VALVES** lick common problems!

Problem No. 1—COMPLETE SHUTOFF. With a continuous, 360 degree, rubber sealing ring, uninterrupted by the valve shaft, *drop-tight* shutoff becomes possible!

Problem No. 2—SEAT LIFE. With the valve disc swinging on an axis eccentric to the valve centerline, the disc lifts away from the body seat upon opening—abrasion and distortion are avoided. Moreover seat life is further prolonged by easy, compensative adjustment.

Problem No. 3—MAINTENANCE. Minimized and simplicity itself due to the unique seat ring principle. No sealing problem around the shaft. The rubber seat is replaceable in or out of the line without dismantling the valve!

Get *all* the facts on performance, sizes and constructions made to A.W.W.A. Specifications. Send for Bulletin SLS-5708.

DARLING VALVE & MANUFACTURING CO.

Williamsport 23, Pa.

Manufactured in Canada by The Canada Valve & Hydrant Co., Ltd., Brantford, Ont.

DARLING VALVES

The American Water Works Association's National Convention — an important event in helping you keep pace with progress.

And a good time to find out for yourself the advantages that Calmet Meters have to offer: sustained accuracy, long life, less maintenance, greater revenue.

Just ask the men who know from first-hand experience!

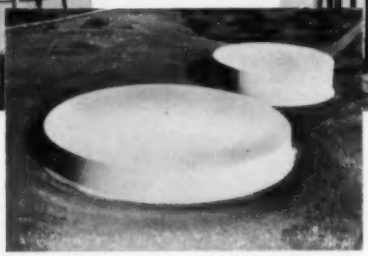
See famous Calmet Meters on display at the Convention.

WORTHINGTON
CALMET METER DIVISION
2301 SO. MAIN
FORT WORTH, TEXAS

,000 gallons

250,000 gallons

1,500,000 gallons



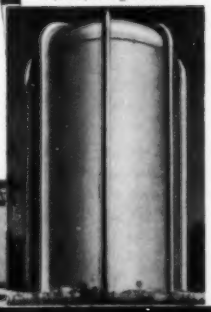
15,000,000 gallons (foreground) 10,000,000 gallons (background)

HAMMOND STORAGE AND PROCESSING VESSELS FOR WATER

HAMMOND Standpipes, Reservoirs, Elevated Tanks, Spheres, Filtration and Purification Units for Water Supply & Fire Protection Systems are built to all standard codes and specifications including those of the American Water Works Association, Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, the Factory Insurance Association.

Catalog H_2O describes **HAMMOND** Water Storage and Processing Vessels . . . Write for your copy.

2,000,000 gallons



30,000 gallons

500,000 gallons

HAMMOND IRON WORKS

HAMONDTANK

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PROVO, UTAH • CASPER, WYO. • BIRMINGHAM, ALA.

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HTH Tablets are easy to use—you simply attach them to the inside top of every pipe. When the pipe is filled with water, the chlorine is carried to all interior surfaces of the pipe. Because the tablets are slow dissolving, they provide a long-lasting chlorine residual throughout the pipeline, assuring complete chlorination.

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K·M
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ASBESTOS-CEMENT PRESSURE PIPE

Its bore stays clean year after year for uninterrupted, trouble-free service

"K&M" Asbestos-Cement Pressure Pipe is as modern as the Jet Age in which we live.

The bore remains smooth and clean always. Pumping costs remain low. Made of tough, high-tensile-strength asbestos fibers and portland cement, it's practically indestructible. Won't corrode or tuberculate. And, it's completely immune to electrolysis. Joints are permanently, automatically root-tight and water-tight.

"K&M" Asbestos-Cement Pressure Pipe is a thrifty pipe. Its lightweight reduces shipping and handling costs. You can install it in practically all kinds of weather and soil conditions . . . with unskilled labor . . . and without heavy machinery. And, lay more pipe per hour than ever before.

What makes "K&M" Asbestos-Cement Pressure Pipe so special? Eighty-five years of asbestos engineering by one of America's pioneers in asbestos products. For more information, write to us today.

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The finest coupling in the industry! Exclusive patented "K&M" FLUID-TITE Coupling connects in two easy steps. Seals tight and stays tight no matter how high the pressure. Self-energizing sealing rings.

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Get the best—
Buy
WATCH DOG
WATER METERS
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NEW JERSEY
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Crystal-pure water comes cheaper with Dicalite

Compared with sand filtration systems, diatomite filtration of municipal water supply with Dicalite Filteraids starts you out thousands of dollars ahead. And the records of municipalities now using Dicalite filtration prove that clarity and purity are at least equal to the best that sand can do. Health department records also verify this.

Cost savings start with the smaller space requirements of a filter system using Dicalite – no more than a quarter of the space needed for a sand system of comparable capacity. Make your own estimates of what this could save you in land and building costs.

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Dependable GLC GREAT LAKES Dicalite FILTERAIDS

DICALITE DEPT.• Great Lakes Carbon Corp.,
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Address_____

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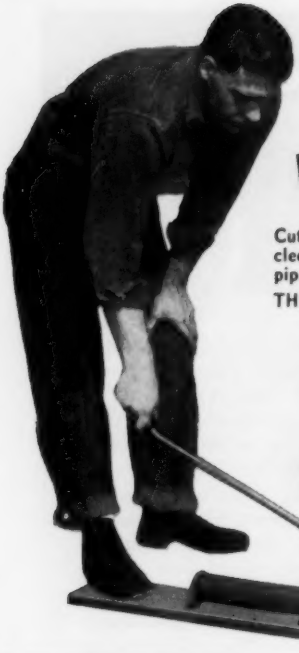

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WHEELER HYDRAULIC PIPE CUTTER

NO VISE — NO TURNING — JUST SQUEEZE AND POP!

Cutter can be used in a ditch to cut pipe in a line with minimum clearance. All that's required is room to wrap the chain around the pipe.

THE HYDRAULIC MODEL CUTS —

- CLASS 150 AWWA WATER MAIN 4" thru 12"
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- CEMENT LINED CAST IRON WATER MAIN 4" thru 12"
- STD. OR XH SOIL PIPE 6" thru 15"
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— less than 2 minutes per cut —
a one man operation.

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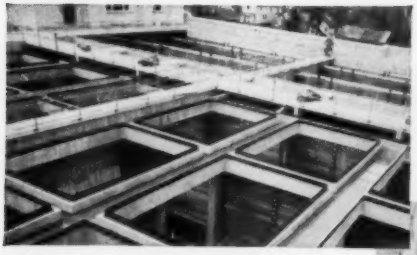
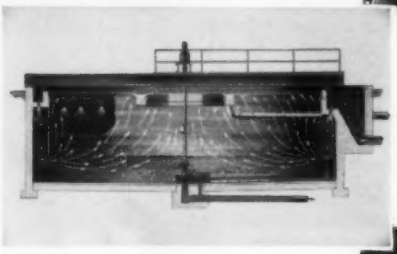


Better Settling. Use of the Rex Verti-Flo Clarifier makes possible improved settling...increases capacities...effects important cost savings.

Better Flocculation. The Rex Floctrol makes possible the production of an optimum floc with the minimum amount of chemicals ...savings in both power and chemical costs.



Better Clarification. Design of Rex Rim-Flo Clarifiers provides increased capacity—maximum efficiency in circular tanks. Entire tank volume is utilized—short-circuiting practically eliminated.

Better Sludge Removal. Rex pioneering in conveyor sludge collector design has led the way to positive, efficient high-capacity removal of sludge from settling tanks...far lower operating and maintenance costs.

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Continuous research and product improvement have long been the guiding principles of CHAIN Belt Company. The important developments illustrated here are but a few of the contributions CHAIN Belt has made toward greater efficiency and economy in the operation of water treatment plants.

A Rex District Sales Engineer will be happy to provide the complete details...or write CHAIN Belt Company, 4609 West Greenfield Avenue, Milwaukee 1, Wis.

Visit the CHAIN Belt Booth No. 74 at the AWWA Convention in San Francisco.

CHAIN BELT

BRINE PIPING

How it can affect design of water softening installations

Delivering brine when and where it's needed depends on several important requirements. For instance, the piping must have adequate capacity . . . fittings and valves should resist corrosion . . . and pumps should be correctly located. With the ever-growing amounts of brine called for in today's water softening installations, it's also important to provide for economical expansion of existing piping layouts as needed.

For expert technical assistance on all questions of brine piping, many treatment-plant designers and builders are turning to International Salt Company. 50 years of experience and continuing research in all phases of salt handling and brine production have made International the leading authority in matters concerning salt purchase, storage and dissolving for regenerating ion exchangers. We'd be happy to put our services at your disposal.

Service and research are the extras in STERLING SALT

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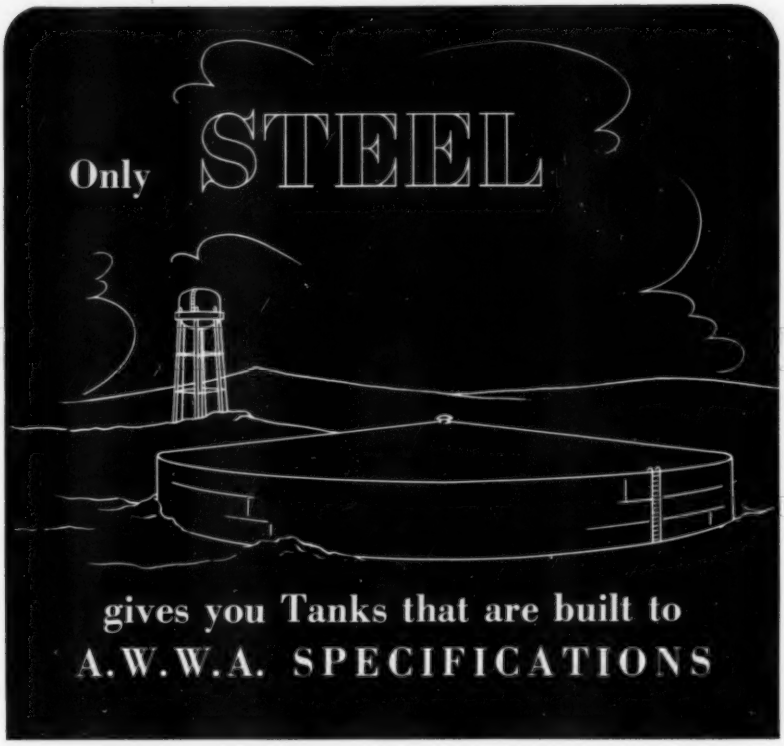

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These specifications—*AWWA D100–55, AWS D5.2–55, and AWWA D102–55T*—were developed by a committee of renowned engineers representing the best knowledge and experience available on the subject of water storage.

STEEL PLATE FABRICATORS ASSOCIATION
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G-A *Cushioned* Altitude Control Valve

Your head will be in the clouds when a Golden-Anderson Altitude Control Valve takes charge of the water level in your elevated tank. From its protected spot in an underground pit this valve constantly maintains the water level and prevents overflow.

Sizes 2" to 36". Pressures up to 250 psi.

Write today for Bulletin W-4B.

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Designers and Manufacturers of VALVES FOR AUTOMATION

MAXIM evaporators

are under constant test at the enlarged Maxim Test Station in Waterford, Connecticut. Full density sea water, in continuous supply, assures the best possible conditions for research, development and testing — another reason why you can specify Maxim with confidence.

Maxim Evaporators may be the answer to your potable water problems. Write for full information.

extra benefits from MAXIM Test Station

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EMHART

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is a Pfaudler Permutit program providing the know-how, the equipment, and the experience for solving problems involving fluids

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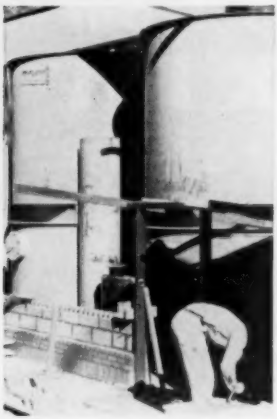
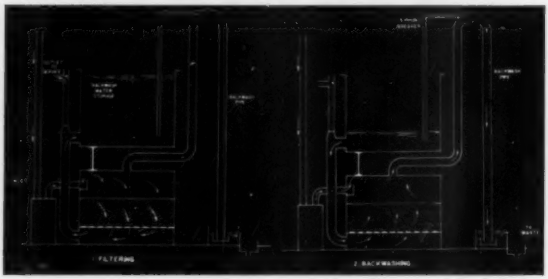
storing
heat transfer
pumping

Whenever you have a fluid-handling problem, put the Pfaudler Permutit FLUIDICS program to work.



Automatic valveless filters, like this tandem setup photographed during its installation at an Eastern municipality, are now in service.



Permutit valveless filter, municipal design

FLUIDICS AT WORK

The only filter that works by itself

We sell most of our Permutit valveless filters simply by pointing out the things you *don't* have to do and the things you *don't* need once you install one:

Manpower — None needed. No valves to operate, gauges to watch, pumps to start or stop, or decisions to be made.

Valves — None. Entire operation is automatic and hydraulic.

Pumps — None needed. All work done by atmospheric pressure.

Rotary wash — None needed. Unit operates only to four- or five-foot head . . . schmutzdecke cannot become packed enough to need breaking up.

Flow controller — No mechanical, pneumatic, or hydraulic devices needed . . . unit filters whatever volume you deliver.

Maintenance — None, outside of normal, routine painting. No moving parts to wear out.

The best part of our story is the fact that this filter costs less than conventional gravity filters, either manual or automatic.

The basic laws of hydraulics behind this filter's design show in the diagrams. If you're rusty on your hydraulics, or are just plain interested, we invite you to write for our bulletin on valveless filters.

Address yourself to our Permutit Division, Department JA-69, 50 West 44th Street, New York 36, New York.

PFAUDLER PERMUTIT, INC.

Specialists in FLUIDICS . . . the science of fluid processes

WATER IS USUALLY GROWTH PROBLEM NUMBER ONE

For growing communities with new residential or industrial developments, the first problem often to be solved is that of an adequate supply of water. Graver has solved this problem over and over again, for expanding towns like Akron, Indiana. This 100 foot high 150,000 gallon elevated water tank for Akron is one of a large number of tanks, standpipes and reservoirs built by Graver—in sizes from 25,000 to 6,000,000 gallons. For help in solving your water needs, call on Graver, fabricators for over a century.

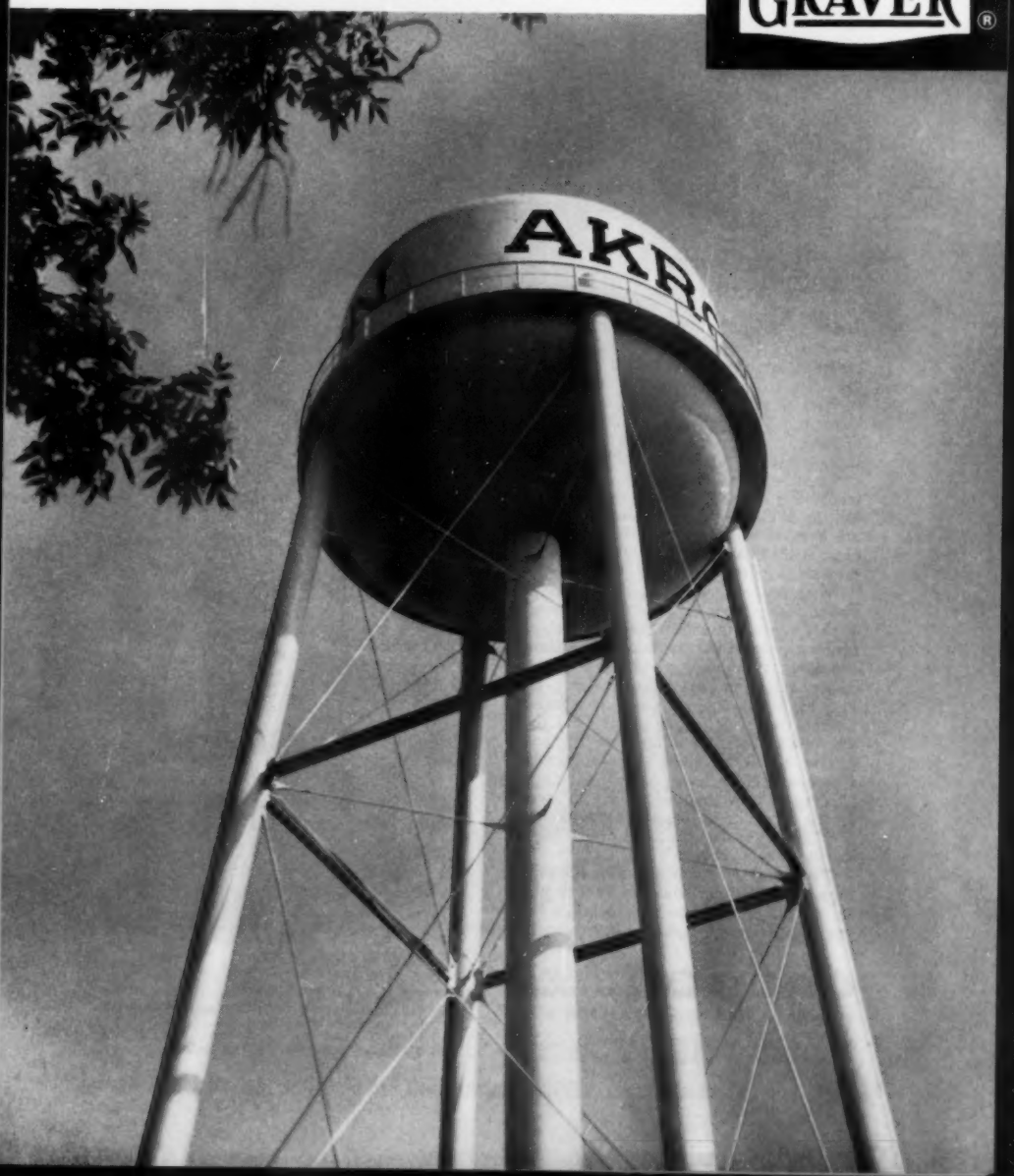
GRAVER TANK & MFG. CO.

DIVISION—UNION TANK CAR COMPANY

Plants and Offices Across America

EAST CHICAGO, INDIANA

GRAVER®



Want cobwebs on *your* complaint phone?

Then use Calgon* — for Calgon stops red water and lime scale — the two main causes of customer complaints. Yes, you can turn complaints into compliments, because whether the "red water" comes from iron present at the source, or iron dissolved from the pipes by corrosion, Calgon treatment is the answer.

When well waters containing iron and manganese are treated with a few parts per million of Calgon, the iron and manganese are kept in solution and the water is as clear at the consumer's tap as it was when pumped from the well.

When red water is caused by iron dissolved from the pipes, it can be prevented with Calgon† treatment because Calgon forms a protective film on metal surfaces. Moreover, this protective film also reduces costly tuberculation damage, flows are kept high and pumping costs are reduced. Calgon treatment is particularly effective after water main cleaning since the protective film forms quickly and tuberculation never gets a chance to start.

A report of a twenty-four month study on the efficiency of Calgon in maintaining pipeline flows is available. Ask for a reprint of this paper.

Write or phone for more information. An experienced Calgon engineer will be glad to make detailed recommendations on your specific problem.

CALGON COMPANY
DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PA.
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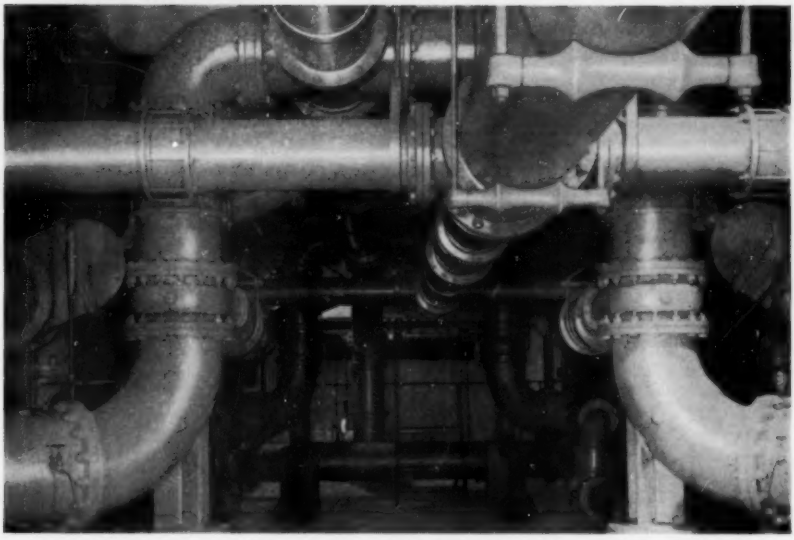
* Calgon is the Registered Trade Mark of the Calgon Company for its glassy phosphate (sodium hexametaphosphate) products.
† Fully licensed for use under U. S. Patents 2,337,856, 2,304,850 and 2,358,222.

EXCLUSIVE! WINCHESTER, VIRGINIA, WATER TREATMENT PLANT beautified and protected exclusively with colorful INERTOL® coatings



PIPE GALLERY: Pipes painted with Glamortex® Enamel—a glossy, alkyd-resin enamel of highest quality. Weather-, wear-, and fade-resistant. Walls and ceiling protected with Ramuc® Utility Enamel—a glossy, natural rubber-base coating. Leaves tile-like, easy-to-clean finish. Both Glamortex and Ramuc in dozens of eye-pleasing colors.

INERTOL COATINGS USED 100%! The City of Winchester aimed for beauty and protection. That's why rugged Inertol paints were chosen for complete protection of the new Percy D. Miller Water Treatment Plant, part of a multi-community, multi-million-dollar water system.

This new 7 MGD system was built to meet the rapidly expanding industrial and residential needs of Winchester and neighboring areas. For long-term maintenance economy...good looks...and lasting protection, Inertol coatings were specified 100% by Alexander Potter Associates, Consulting Engineers, New York, N. Y., Mr. M. H. Klegerman, Engineer.

Specialized Inertol coatings are specified year after year by consulting engineers to withstand corrosion, submersion; outdoor and indoor use. A paint best suited to solve *your* problem can be selected from Inertol Company's complete line.

Buy Inertol paints direct from the manufacturer. Shipment within 3 days from our plant, or nearby warehouse stocks. For valuable maintenance painting guide with handy paint selector chart, write today for free folder W587.

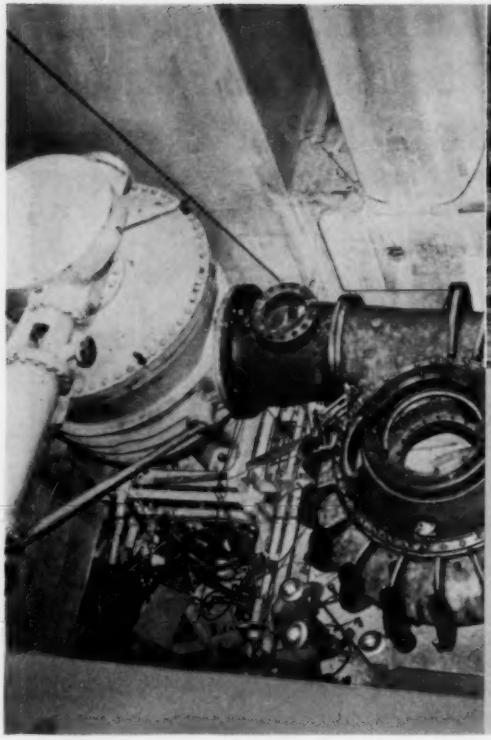
Ask about Rustarmor®, Inertol's new hygroscopically controlled rust-neutralizing paint.

INERTOL CO., INC.

484 Frelinghuysen Avenue, Newark 12, N. J. Inertol 27-G South Park, San Francisco 7, Calif.

A complete line of quality coatings for water, sewage and industrial wastes plants and swimming pools.

Visit our Booth No. 131 at the AWWA Convention, San Francisco, Calif., July 12–17, 1959



TOP Downhill view from Iron Mountain tunnel inlet on the Colorado River aqueduct shows the first two conduits and pumping station with the reservoir and aqueduct in the background. Excavation at the right now houses a third set of pumps, and a third conduit has been added. Nine A-C Rotovalves are used here for pump discharge service.

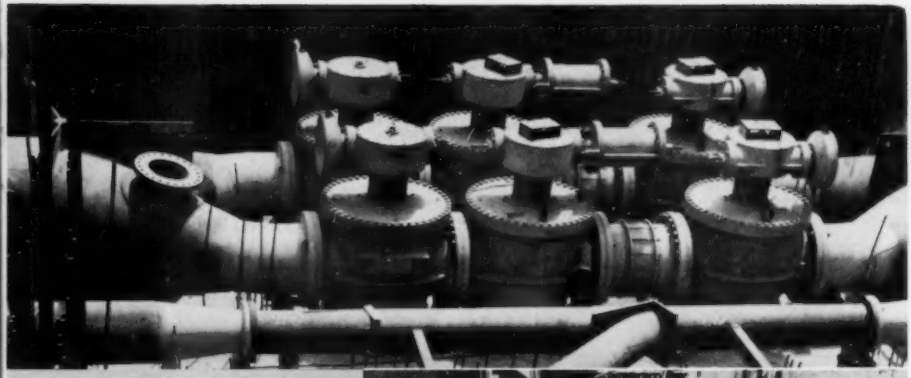
LEFT Construction view shows 48" x 64½" tapered Rotovalve being installed with an Allis-Chalmers centrifugal pump at Iron Mountain Station.

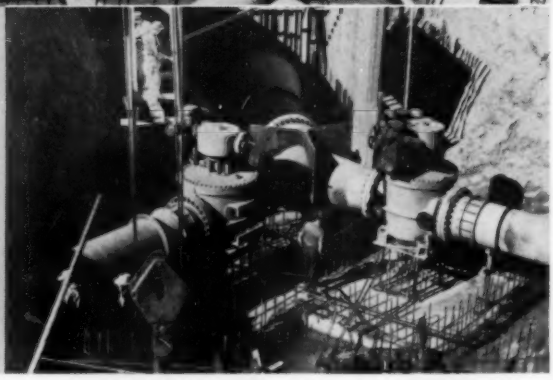
112 ALLIS-CHALMERS
METROPOLITAN WATER DISTRICT

A total of 563 Allis-Chalmers Rotovalves, in sizes from 6" to 64½", have been installed on water service throughout California in the last 25 years. The Metropolitan Water District of Southern California itself uses 112 of these Rotovalves in its Colorado River aqueduct and distribution systems. This aqueduct is part of a long-range program for increasing the water supply for the 7,000,000 people of the area it serves.

The flexibility of A-C Rotovalves suits them to any type of operation, any method of control, or any sort of location. In pump discharge service, the inherent characteristic of a large reduction of flow area during the early part of the closing stroke makes them ideally suited to control surges in the event of emergency shutoff. Full-line port opening means least possible pressure loss, and valve operation is quick and easy.

Allis-Chalmers offers you a complete line of Rotovalves, ball and butterfly valves for any water service. For full information, contact your nearest A-C





TOP Six 30" Rotovalves are being installed in the Covina Pressure Control Structure between the LaVerne Filter Plant and Garvey Reservoir.

RIGHT Two 36" A-C Rotovalves connect to an energy dissipator on the Middle Feeder Line Discharge to the Alhambra Wash for ground water replenishment.

ROTOVALVES INSTALLED BY THE
OF SOUTHERN CALIFORNIA

valve representative, or write Allis-Chalmers, Hydraulic Division, York, Penna.

Rotovalve is an Allis-Chalmers trade name.

See us at the AWWA Exhibit
San Francisco, July 12-17
Booths 67 to 69, 78 to 80

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AWWA Standard Bell Spigot Watermain Fittings—2" through 36".

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Short Body and Mechanical Joint Watermain Fittings—2" through 20".

Fluid-Tite Fittings 3" through 12" Class 150.

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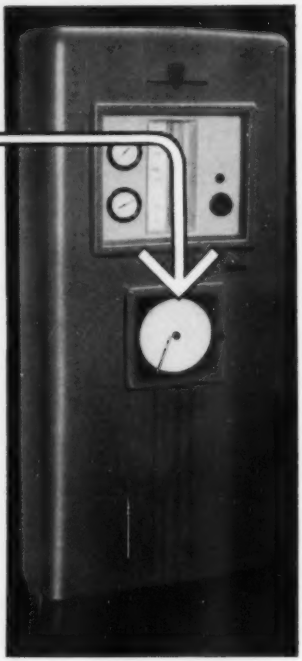
"You can't buy a better Water Meter than HERSEY."

announcing

announcing

a new chlorine flow recorder that's

BUILT IN FOR CONVENIENT USE



The W&T Series A-733 Chlorine Flow Recorder

Now you can buy a compact new chlorine flow recorder that's mounted right in your chlorinator cabinet for convenient use —the Wallace & Tiernan Series A-733 Chlorine Flow Recorder.

This reliable recorder is designed for use with most V-notch Chlorinators. Its effective mechanical operation, made possible by the simplicity of the V-notch Variable-Orifice, assures an accurate record of chlorine flow.

The A-733's linear charts, calibrated to match the rotameter, have equally spaced graduations for easy reading. The charts provide permanent records useful to check the operation of equipment or the amount of chlorine fed during unattended periods. With the A-733, containers can't run dry: You know chlorine consumption to the pound.

An optional vacuum switch warns of any interruption of chlorine flow. It moves the recording pen to a check line and actuates an accessory alarm.

See the new Series A-733 Recorder at Booth 184, AWWA Convention in July.

Get more information today. Write for publication S-139.05

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 51 • JUNE 1959 • NO. 6

Fifty Years' Experience With Water Utility Costs and Revenues

Louis R. Howson

A paper presented on Mar. 12, 1959, at the Illinois Section Meeting, Chicago, Ill., by Louis R. Howson, Partner, Alvord, Burdick & Howson, Chicago, Ill.

FIFTY years ago the regulation of public utilities as it is today was unknown. Wisconsin had its railroad commission, but other state regulatory bodies were not yet in existence. Most of the midwestern public water systems had been built in the two decades from 1880 to 1900, and many were originally constructed by private companies operating under franchise, usually running for a 20–25-year period. Frequently these franchises prescribed rates as well as conditions of service, both of which were considered firm contractual obligations.

Many of the franchises were terminating in the 1900's. Some were renewed, but in a large number of others, the cities elected to exercise the option, usually contained in the original franchise, of taking over the property rather than extending the franchise for another period. When such a decision was made, the value of the property had to be decided. Many franchises specified that the purchase price should be determined by an arbitration board consisting of three nationally known engineers: one selected by the city, another by the water company, and a third or neutral arbitrator selected by the other two. In most cases the decision of the arbitrators was binding, at least upon the water company, but frequently not upon the city. Some arbitrations resulted in extended litigation with decisions establishing new public utility law, as in the famous cases of the National City Water of Kansas; Dubuque, Iowa; Knoxville, Tenn.; Omaha, Neb.; Des Moines, Iowa; and many others, some of which terminated in the US Supreme Court.

Determination of Rates

Rates were usually specified in the franchises. The economy was slowly changing, and over franchise periods of 20 years or more the value of the dollar diminished. With the decline

of net income because of rising costs, combined with the undue optimism about the early earnings of water works among those seeking franchises, a very large percentage of the private water works built prior to 1900 went bankrupt. By 1920, many states had created public utility commissions responsible for fixing value for rate-making purposes and fixing rates fair both to the utility and the public.

Early Operation

Water works operation in the early days was not a simple matter and progress was slow. There were only 17 water works in the United States in 1800; only 83 in 1850. By 1900, owing to the large number of water works constructed in the last two decades of the nineteenth century, there were 4,000 public water supplies. By 1924 the number had reached

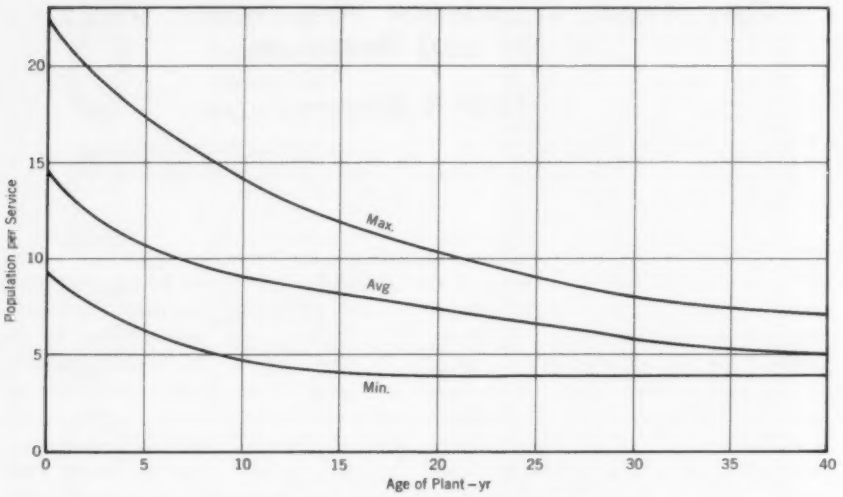


Fig. 1. Rates of Service Growth

The curves were plotted from the statistics of 72 water works in the Middle West

These commissions determined fair rates rather than perpetuate the franchise rates agreed upon under economic conditions quite different from those prevailing after World War I. Many water companies owe their solvency to the early decisions made by these commissions. During this inflationary period, had the utilities been required to give service at the rates prescribed in the franchises, most of them would have gone bankrupt.

7,650, and at the present time there are approximately 18,000 public water supplies in the United States.

It was exceedingly difficult at first to get consumers to use public water systems. Often the public supply, though large enough, was neither as palatable nor as safe as the water from individual wells. In the Middle West, on the average, water works systems did not attain a ratio of one service to each five inhabitants until about 40

years after original construction. This lag in use and revenues seriously affected the earnings of investments in water works properties. There was a long and costly development stage before a new water works became financially successful.

In order to ascertain the facts concerning the rate of acquisition of services, statistics of 72 midwestern water works, obtained by the author's staff, were plotted on a graph (Fig. 1). This study, made in 1910, shows that on the average, 7 years after a water works was completed it had only one service for every ten inhabitants, and that in some cities it took more than 20 years to arrive at this ratio. Today most water works have a saturation of one service for every four or five inhabitants; competition with the backyard well no longer exists in most localities where a public water supply is available. It should be noted, however, that even now many new suburban subdivisions depend upon individual wells and cesspools. There are 265,000 people in the Chicago area alone who do not use water from a public supply.

In 1897, a tabulation of water works with respect to ownership (*1*) showed that of the 716 water works in Illinois, Indiana, Iowa, and Ohio, 149 were privately and 567 municipally operated. This ratio of approximately 20 per cent private to 80 per cent public ownership was probably indicative, with some variations, of the ratio throughout the country. In 1924, 5,077 plants of a total of 7,651 were municipally owned; that is, approximately 70 per cent (*2*).

Sometimes a plant was built by a city and later acquired by a private company; Peoria, Ill. is an interesting example. The Peoria plant, built in 1866 by the city, took water from the Illinois River. In 1889 the city plant was sold to a private company. Peoria is still served by a private company, which abandoned the Illinois River as a source of supply and developed a shallow ground water supply.

Plant Financing

Originally, municipal plants had to be financed by general obligation bonds; expansion was therefore sometimes difficult or impossible. Approximately 25 years ago, most states enacted legislation authorizing revenue bond–type financing, in which the bonds were a lien only on the water works property and its revenue, with the cities pledging to provide the money necessary to pay the interest and amortization on the bonds. This type of financing has been highly successful, with the result that for the past several decades municipalities have expanded their water systems at a much more rapid rate than the private companies. For example, a comparative study made of investment growth in private and public plants from 1925 to 1945 showed that the municipal rate of investment in new plant was $2\frac{1}{2}$ times that of the private rate. In the next 10 years, from 1945 to 1955, the municipal water works' percentage growth in investment was four times that of private companies. As a result, the outstanding debt of municipal water works in 1955, expressed in dollars per capita served, was double what it was in 1945. In only six states are the financing and rates of municipal water works regulated by public service commissions. The private companies, largely because of their regulation by public utility commissions, have maintained a more level debt over the same period.

Municipalities can issue revenue bonds for 100 per cent of their cost. These bonds are tax exempt and command low interest rates. Utility commissions usually limit private company financing by bonds at about two-thirds of book cost, with an interest rate currently about 50 per cent higher than that for the tax-exempt municipals.

Revenues and Costs

In 1910, the author compiled the statistics of more than 100 water works

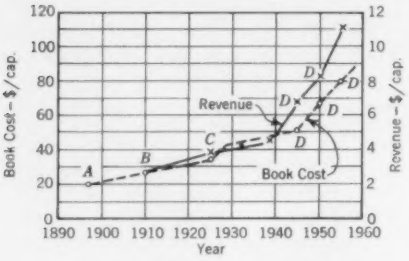


Fig. 2. Per Capita Revenues and Book Costs—1896–1958

The lettered points represent data plotted from: A, *Baker's Manual* (1); B, *Alvord and Burdick;* C, *author's analysis of 100 plants;* D, *Seidel and Baumann* (3).

plants to ascertain the range in per capita revenues and investment costs. As of 1910, 102 plants for which statistics were available had an average revenue per capita of $2.62. A 1955 statistical analysis of water works data (*3*) showed a revenue averaging $10.65 per capita for public plants and $12.16 per capita for private plants, with a weighted average of approximately $11.00 per capita, or slightly more than 400 per cent of the per capita revenue of 1910.

The late Edward Bartow, addressing the first meeting of the Illinois Water Supply Association in 1909, when he was the Secretary of the Illinois Section, stated:

> A conservative estimate of the value of the water works plants of the state outside of Chicago indicates that upwards of $15,600,000 is invested. Not only is a considerable sum of money involved but also the health and welfare of a large proportion of the inhabitants. In the towns outside of Chicago that are supplied by water works, there are 1,129,000 people. This represents an investment of $13.85 for each person.

This estimate is probably too conservative, for at the same time, the city of Chicago, then serving 2,300,000 people, had invested about $56,000,000 in its water works, the equivalent of $24 per capita.

The Alvord and Burdick study made in 1910 showed that the weighted average investment in 102 water works was $25.20 per capita. The Seidel-Baumann study of 1955 data showed an average book value of public plants of $82, private plants $68, or a weighted average of approximately $80 per capita, a figure $3\frac{1}{6}$ times that of 1910. Also shown was that the book value of public plants had increased $30 per capita in the period 1945–55, whereas the book value of private plants had increased only $8 per capita. This 4:1 ratio of investment growth of publicly as compared to privately owned water works is believed to be largely because of the reluctance of regulatory commissions to recognize changing economic conditions when determining rate base and rates.

Figure 2 shows the per capita revenues and book costs of water works from 1896 to 1958. Although the data plotted are not from the same plants,

TABLE 1

Approximate Costs of Water Works in United States

Year	Population Served *1,000,000*	Investment per Capita *$*	Total Investments *$1,000,000*
1896	22.7	20.00	450
1910	38.0	25.20	960
1920	50.0	32.00	1,600
1946	90.0	55.00	4,950
1958	120.0	100.00	12,000

and therefore may not be strictly comparable, they nevertheless indicate that the accumulated book cost of water works has grown 300 per cent during this 62-year period and that the revenues have increased from $2 to $11 per capita, a gain of 450 per cent. The present-day average cost of providing water works facilities is at least $250 per capita. Figure 2 also indicates that revenues and book costs followed nearly parallel courses from 1896 to 1940, but that after 1940, revenues per consumer increased at a faster rate. This should not be interpreted, however, to mean that water works are in better financial condition now than they were in 1940. Adequate water works revenues must be sufficient to cover both fixed charges on capital costs and operating and maintenance costs, including depreciation. During the 10-year period 1945–55, the unit operation and maintenance costs of water works, both municipally and privately owned, have increased more than 75 per cent. The percentage increase in total operating cost has been materially greater. During this period the book value per capita has increased only about 45 per cent, although the dollars invested have increased 100 per cent. This difference illustrates the lag resulting from the use of accumulated original cost rather than present-day cost. It is also an example of long-time water consumers paying a large part of the cost of furnishing water to new consumers.

Expansion

The growth in the number of water works systems in the United States in the past 160 years, shown in Fig. 3, indicates that one-half the total of 18,000 water works serving the public were built in the last 30 years. Because of the rapid expansion in urban growth, the population served, now totaling approximately 120,000,000 people, has also doubled in the past 30 years. It is apparent from the foregoing that at least one-half the water works of this country have been built during a period of unprecedented inflation.

Table 1 shows the approximate costs of water works for varying periods. The incremental per capita costs during the several periods, shown in Table 2, are even more important.

Of the total investment in public water supplies at the present time—about twelve billion dollars—six billions have been expended in the last 10 years. In other words, there has been

TABLE 2

Incremental Costs of Water Works in United States

Period	New Investments *$1,000,000*	Population Growth *1,000,000*	Per Capita Investment *$*
Prior to 1896	450	22.7	20.00
1896–1910	510	15.3	33.30
1910–20	640	12.0	53.00
1920–46	3,350	40.0	83.75
1946–55	7,050	30.0	233.00
1959			250 +

as much money spent for water works in this country in the last 10 years as in the prior 150 years. Unfortunately, because of inflation the number of facilities built are not in proportion to the amount of money spent. In fact, the money expended during the past 10 years bought less than 20 per cent as many facilities as could have been purchased in the period 1890–1930, and only about 10 per cent as many as could have been purchased prior to

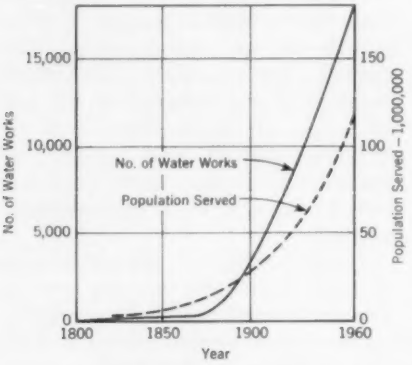


Fig. 3. Relationship of Population Growth to Water Works

The data plotted are from water works in the United States.

1900. Seventy-five per cent of all the money invested in water works in the United States has been expended since 1943—that is, three times as much money has been invested in water works construction in the United States in the last 15 years as in the preceding 140 years put together. At least three times as much per capita must now be invested annually for water works construction as was expended in the period 1925–45, if we are just to keep up with the expansion during this period, half of which was during an economic depression and half during war years with restricted construction. When corrected for the increase in population served, this needed investment exceeds four times the 1925–45 rate, and that was in a period during which a backlog of deficiency was accumulating.

Fair Value

Water works are subject to the same economic laws as nonutility industries, and if they are to survive under private enterprise, they must be allowed to earn on fair value. In the National City Water Works case in 1897, the court first enunciated the principle of public utility evaluation: cost of reproduction less depreciation is the measure of fair value. That in general continued to be the precedent followed by the courts for the next four or five decades. During that time, following the inflationary effects of World War I, the US Supreme Court, in cases such as Bluefield Water Works, Southwest Bell Telephone Co., and Indianapolis Water Co., reaffirmed the principle that original cost was not fair value, and that major consideration in determining fair value must be given to cost of reproduction less depreciation.

In the Hope Natural Gas case, which came to a hearing and reached the Supreme Court during World War II, the company's operations were surrounded by a unique statistical financial position. In its Hope opinion, the Supreme Court adopted a rate base that was original cost. The rate base fixed by utility commissions at the present time varies from original cost less the book reserve to cost of reproduction less accrued depreciation.

The utility commissions in Illinois and Indiana have made decisions that reflect a consideration of reproduction cost, which the courts in those states have stated as necessary to conform to the statutory provision that fair value be the rate base.

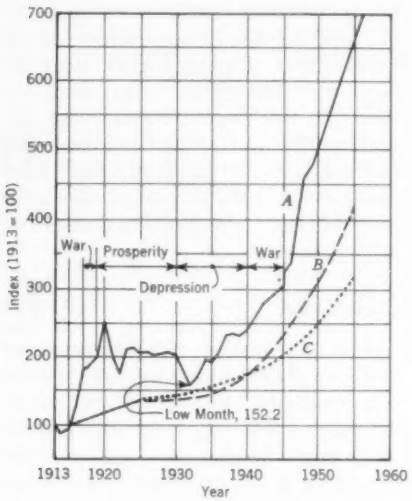


Fig. 4. Relationship of ENR Construction Cost Index, per Capita Revenue, and per Capita Book Cost

Curve A represents ENR Construction Cost Index; B, per capita water works revenue; C, per capita water works book cost. The data were plotted from annual averages.

Other Revenues and Costs

World War I resulted in violent changes in world economics that were reflected directly in construction costs. Labor costs rose sharply. Construction costs do not reflect the entire increase in labor costs because of increased mechanization in the manufacture of materials and their installation. Various construction cost indexes have been widely used, and some of them, such as the *Engineering News-Record* (ENR) Construction Cost Index, the ENR Building Cost Index, and the Handy Whitman Index, have proved reliable. Probably the best single index indicating the change in overall costs affecting entire water works systems is the ENR Construction Cost Index.

In Fig. 4, the ENR Construction Cost Index is shown for the period 1913–59, with 1913 as the base year (equals 100 per cent). Two other curves have been drawn, representing the per capita revenue and the cumulative book cost of water works, both as related to 1913 equals 100. The graph indicates that although construction costs now are at a level of about 7½ times greater than that of 1913, water works revenues have increased only about 415 per cent, and the accumulated original cost of water works only about 315 per cent. The discrepancy between the accumulated book cost figure of 315 and the cost of reproduction at current prices of about 765 is basically because of fixed rates and resulting revenues for water works service at the present time. So far as is known to the author, the Ohio Commission is the only state regulatory body that is required by statute to base rates on the cost of reproduction less accrued depreciation. Some states adhere strictly to a rate base arrived at by taking the cumulative original cost less the depreciation reserve. Such a rate base is at the present time usually less than half of what it would be if cost of reproduction less depreciation were adopted.

In general, water works subject to regulation do not ask for an increase

in rates based on full costs of reproduction less depreciation. This would require an increase so large that such requests are generally considered inexpedient. Eventually, privately owned water companies must secure more realistic rates based upon a greater consideration of cost of reproduction if they are to compete with other industries, whose sales are unregulated except by competitive conditions, and whose depreciation charges and, in large measure, fixed charges are based upon current price levels.

Recently in the author's office a comparison was made of about twenty water works valuations in which the original cost of the property and the cost of reproduction were determined. The cost of reproduction of these plants varies from 175 per cent to 250 per cent of the original cost less the reserve. The individual variations are largely a reflection of the amount of construction during high-cost levels. In general, the more rapidly that plants have expanded in recent years, the less is the percentage relationship between cost of reproduction less depreciation and original cost less the reserve.

It is interesting to note that in determining the prices at which the actual transfers of water works properties from private to public ownership are being made, the cost of reproduction less depreciation is the dominant consideration. With three properties, the transfer of which the author participated during the past year or two, the average relationship of the purchase price to the original cost less the reserve was 173 per cent, and all three figures were within 5 per cent of this average. Two of these properties have grown very rapidly since World War II. This evidence of transfer or market value is further proof of the inadequate consideration frequently given by regulatory commissions to the cost of reproduction.

Of course, a city that floats tax-exempt revenue bonds for 100 per cent of its water works acquisition can afford to pay a price higher than the book cost (which in many cases has been the rate base), because the private utility must pay approximately half of its net earnings after fixed charges for federal income taxes, as well as pay substantial amounts for local taxes.

Conclusion

The construction of adequate water works facilities is far from completed. The magnitude of expenditures is declining. Facilities, not dollars, provide water service, and it now takes ten times as many dollars to provide facilities as it did at the beginning of the period under consideration. Adequate rates are essential to adequate service; therefore, realistic consideration must be given to changing costs if high standards of service are to be maintained.

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The Needs of Water Utilities

Raymond J. Faust

A paper presented on Mar. 11, 1959, at the Univ. of Minnesota Water Works School (cosponsored by the North Central Section, AWWA), Minneapolis, Minn., by Raymond J. Faust, Exec. Asst. Secy., AWWA, New York, N.Y.

BEFORE the needs of water utilities can be discussed and the problems solved, it must be known what the utilities now have and what they are doing with it. The water industry has accomplished much. The 130,000 people who operate it have many reasons to be proud of its position. It serves 125,000,000 people in the United States and about 12,000,000–13,000,000 in Canada. This magnitude of service, though significant in itself, is not the most important part of the story. For the water served to these 137,000,000 is both safe and palatable, making the accomplishment qualitative as well as quantitative. These systems, about 19,000 of them (18,000 in the United States), have contributed materially to the health, welfare, and economic advancement of the two countries and, if given the opportunity, will continue to do so in the future.

Today, waterborne enteric infection is a thing of the past for users of public water supplies. It took 75 years and many dollars to eliminate it, but the result has been worth both the effort and the expense. Most manufacturing plants depend on public systems for water, and their needs are constantly increasing. Also, today as in the past, water from public systems provides the first line of defense against fire. Cities and towns could not have developed without these sources of water supply. It follows, therefore, that if a nation for any reason lacked adequate and dependable public water service, its position in the world would soon deteriorate. Water systems are basic to individual and material well-being, too. Thus, trends and deficiencies that tend to make water utilities unable to give adequate and dependable service must be quickly recognized.

Present and Future Needs

Today the great majority of water utilities in the United States and Canada are in a precarious position, with regard to plant conditions and finances. Also the leadership and vision so necessary to their operation are too often lacking. Inadequate leadership probably is the most serious deficiency, for with effective leadership, all things are possible; without it, conditions can only become worse.

The lack of decisive leadership in the operation of water utilities is found not only at the local level but at the state or province and federal levels as well. For years the need for a clear and concise national water policy has been studied and reported to the President and Congress. To date, in the United States, such a policy is still

lacking. Although the time for a decision is getting closer, a comprehensive policy will not be adopted by Congress until the demand for it is more clearly expressed by the people.

The states and provinces are also being forced to face their water problems. They are realizing, too, that fresh water is a limited resource that must be used carefully and wisely for the common good. The ideal situation puts the state in control of all use and diversion of water.

In the United States and Canada, municipalities, counties, and districts are largely responsible for developing and operating public water systems. They have done well in supplying 137,000,000 people, innumerable factories, and many commercial establishments, working on a budget that has usually been inadequate to maintain the physical plant and operating staff in prime condition. To continue with such sparse financing would be foolhardy and disastrous. Today, the United States alone has a backlog of over 2.6 billion dollars in proposed and needed water works construction, and the amount is still increasing. By 1975, the United States must be prepared to serve an additional 50,000,000 or 60,000,000 people. To put itself in a position to render good water service now and in 1975 is the big task that faces the industry. To improve its present unsatisfactory position, it must take a new look at the problems involved, arrive at the solutions, and then sell the solutions to the people.

Plant Deficiency

Plant deficiency is a serious problem that will take time and money to correct. An example of the type of deficiency that makes headlines in the local papers is inadequate supply. In 1953, during a 9-month period (January through September), 1,072 public water supplies in the United States were forced to restrict the use of water to part or all of their 24,000,000 customers. In almost every case the lack of an adequate supply of water was manmade. *The local authorities failed to recognize the symptoms of inadequacy in time to prevent an actual shortage.*

There are many types of plant deficiencies that can cause real problems for management and the public unless they are recognized early and immediate steps are taken to eliminate them. A few examples are:

1. Inadequacies in the water-carrying capacities of portions of the distribution system, resulting in low pressure areas and inadequate fire protection

2. Lack of adequate treatment facilities, permitting hard, corrosive, staining, or unpalatable water to reach the customer

3. Lack of 100 per cent metering, conducive to the waste of water and also representing poor business methods

4. Inadequate pumping facilities and the lack of alternate power sources, resulting, in the event of fire, in many anxious moments for management and the owners of homes, stores, and factories

5. Lack of adequate water storage reservoirs, jeopardizing continuous and adequate service.

It is agreed that plant deficiencies are to be avoided, but few persons have the training and experience to ferret out the deficiencies in time to do something about them. For this reason, and because of the lack of public support, plant deficiencies are common, in fact

too common. A survey made by USPHS (*1*) of utilities serving communities of 25,000 population and larger indicates that:

1. One of five water utilities is deficient in supply.
2. Two of five are deficient in transmission capacity.
3. One of three is deficient in pumping capacity.
4. Two of five are deficient in treatment capacity.
5. Ground and elevated distribution storages show deficiencies of 29 per cent and 43 per cent, respectively.
6. Distribution system improvements are required in 57 per cent of the water systems.

To recognize plant deficiencies, regular engineering appraisals should be made as a preventive maintenance measure. To locate and meet plant problems while they are small and easily corrected is a sign of good management. The alternative is to wait and do nothing until the problems are apparent to everyone and a state of emergency exists. Though the choice of action here needs no elaboration, too many water utilities are still operated along a "delayed-action" plan, simply because the problems or their serious aspects are not recognized until too late.

Inadequate Leadership

Water utility operation is a business, and as with other businesses, superior service is the result of superior management. Unfortunately, the water industry is not adequately favored with professional management. Some utilities in larger cities have excellent staffs, but as the size of utilities decreases, professional staffs are found less frequently, until they become almost nonexistent in the smallest communities. Fortunately for the public, the staffs, irrespective of their professional attainments, are completely devoted to giving service.

The extent of plant deficiencies listed above may be proof that management is often inadequate also in the larger utilities. These deficiencies are most often found in utilities under public rather than private ownership, a sad commentary on the neglect local government has given to one of its basic responsibilities.

Financial Considerations

Perhaps the key to the solution of the major difficulties facing the water industry is more money for services rendered. Plant deficiencies and inadequate management are both symptoms of the same "disease"—financial malnutrition. Most publicly owned systems need rate increases, which should be based on present requirements and on those for 5, 10, 15, and more years in the future. If such rate schedules are to be realistic, they must be based on facts resulting from an engineering survey. Too often town councils base their water rates on the schedules of neighboring towns, with no relation to the facts of local operation. It is no wonder that some water systems operate on insufficient funds and are unable to give adequate service.

Today, as always, the cost of water is the biggest bargain in family and industrial budgets. This would be true even if local water rates were increased 200, 300, or even 400 per cent. Fortunately, such steep increases seldom are required, although increases of 50–100 per cent are presently needed by many utilities to insure good

service, a quality product, and the ability to serve the influx of people expected in the near future.

Size of Utilities

Before these problems can be solved, something should be known about the size of water utilities. For example, there are about 18,000 public water systems in the United States. Of this number, 86.4 per cent serve less than 5,000 people, 93.3 per cent less than 10,000. All but 2.7 per cent of the 18,000 utilities serve less than 25,000 people. In other words, the great majority of the systems are in small towns, which, unfortunately, have a minimum of professional engineering talent available to keep the necessary records of operation and maintain a constant appraisal of utilities for the detection of inadequacies. Thus, the inability to recognize system problems until too late constitutes a basic management deficiency.

The record of deficiencies listed earlier indicates that the larger communities (more than 25,000 population) also lack effective engineering talent, so that the problem of plant deficiencies is common to large and small utilities alike.

Use of Consulting Services

To correct plant deficiencies, utilities must first be able to recognize them in time to take action before service is curtailed. To do this requires the services of an experienced engineer, employed by the utility either on a full-time basis or as a part-time consultant. Where a consultant is employed, his services should be used on a regular schedule—for example, every 4 or 5 years as a maximum interval. The consultant should make a thorough appraisal of the system and report the results to the directors (council, commission, board) verbally and in writing; these reports should then be made public.

The cost of an engineering appraisal will vary with plant size, but the total cost will be within the financial limits of the utilities. Such engineering costs prorated over 4 or 5 years become insignificant. Thus, good engineering advice is well within the reach of the smallest as well as the largest systems and should be considered as a regular maintenance expense. Actually, good engineering advice is the least expensive item a utility can buy.

The regular engineering appraisal should point out both present and future needs and list their priority for correction. It should explain how best to eliminate the deficiencies and also provide an estimate of cost. Appraisal reports will not normally include construction plans and specifications for recommended alterations. Those services are separate and in addition to the appraisal report.

Perhaps an engineer's services can best be understood if related to the service provided by a doctor of medicine. It is usually recommended that an individual have a physical checkup each year to learn if he actually is as well as he feels. The physical examination by the doctor corresponds to the appraisal survey of the water system by the engineer, and a modest fee is charged in both instances. If, however, in the initial examination the doctor discovers the first symptoms of a serious condition, he will immediately prescribe a plan of action to cure, remove, or delay the effects of the difficulty. For the application of this additional service another fee will be

charged. Similarly, when the engineer prepares plans and specifications for the correction of a deficiency in a utility, he also makes another charge, the amount of which is in proportion to the amount of his time involved.

Adequate Leadership

The manager of a water utility must know much more than how to operate the system, although too many managers or superintendents are really only operators. They do not take part in supervising billing and accounting; keeping the operating and engineering records; considering present and future needs; making leak surveys; preparing annual reports; or acquainting and selling the council and people on the needs of the utility. These functions are too often the responsibility of others. With an operator for a manager the local water utility is almost certain to give minimum service and be operated on a hand-to-mouth basis. Such a setup lacks managerial leadership and suffers accordingly. Thus, without a true appraisal of the situation, community officials are most likely to do nothing until circumstances force the issue. This is scarcely the recommended way to administer a service organization.

If the town is large enough to have a city engineer, it is almost certain that his time is more than completely occupied with a multitude of maintenance and operating duties, including those pertaining to streets, drainage, sanitary sewers, buildings, water, and several other engineering functions, leaving him little if any time for appraisal and planning. Again, adequate administrative leadership is missing, except in rare instances. The same conditions often prevail with a council–city manager administrative setup, particularly if the manager is also the city engineer with all the duties that the job implies. Again, because of his many functions, the water utility, as well as other city services, too often suffers. There is nothing wrong with the city manager type of administration in itself. It functions best, however, where the manager as the city administrator works with qualified division heads, including the head of the water utility division, in the operation of the several city departments. An administrative setup of this type can work to the advantage of the utility and the people; the combination of a qualified city manager and a qualified director of the water department, working as a team, can give the time and the leadership needed to keep water utilities in sound condition.

Perhaps the type of publicly owned water utility administration that offers the most favorable climate for high-quality water service is that provided by a local water board or commission. Under this type of administration the directors of the utility have ample time to consider the many difficult and complex problems of water supply and to reach objective decisions. The problems of a water utility relate not only to the present but also to many years in the future. For example, the source of water for a town must be ample for the present and also for at least 5, 10, or more years later. Water mains, particularly the larger feeder mains, must be designed and built to supply water that will be needed in 50 or more years. But spending large sums of money for projects that will not immediately realize their full capacities is sometimes difficult for a city council to under-

stand and approve. The inclination too often is to spend money where results can be seen and immediately appreciated by the people. Unfortunately, utilities cannot be operated on that basis if a satisfied customer is the prime objective of management. For that reason, local boards or commissions, whose members are not subject to frequent changes and who need not think of reelection, have a much better chance of developing and applying businesslike policies to the operation of the utility. Such policies usually result in long-term benefits for all. A board or commission composed of prominent citizens who are unpaid also provides the type of leadership needed to secure the attention and serious consideration of its proposals for the strengthening of the utility.

Where strong utility leadership is lacking, as it so often is under a mayor-council administration, a water utility deteriorates in plant and service. When the service becomes poor and complaints are more frequent, an emergency develops, and the city council is pressured into a sizable emergency program to correct the deficiencies. The utility, under such conditions, exists in a feast-or-famine atmosphere, and the people pay the price in poor service. Utilities prosper and provide better service where the reins of administration are held firmly by a local board that has only one objective in mind: to give the people high-quality service at a reasonable price. The many city councils that do not provide this type of qualified management should seriously consider turning over to a local board the administration of the system. In doing this, the council will be recognized as having a genuine interest in efficient service.

Although certain types of administration are conducive to utility well-being, it must be acknowledged that a qualified water utility manager can do a good job in most circumstances if given half a chance. The difficulty here is that qualified managers have not thrived under mayor-council administrations and are not now sufficiently prevalent to stem the tide of inefficient operation.

Maximum Efficiency

Because a water utility is a business operation, it should be financially self-sustaining. Its maintenance, debt, operation, and other obligations should all be paid out of income. That this can be done is exemplified by many publicly owned utilities throughout the country. To make it possible, the city council should give the utility management sole responsibility to supply the water needs of the community with quality service at a fair price established by a local water board. To accomplish these objectives, management must keep the system in good repair, and plan and construct additions in accordance with a well defined master plan. The board must also report the status of its business regularly to the council. The utility in turn should give annually to the general fund of the city an amount of money equivalent to all local property taxes based on the assessed value.

In such an atmosphere the utility can be expected to do a superior job and also help attract industry. The city council in turn will be relieved of a problem that can be vexing and take much of its time. It will also have the satisfaction of knowing that

the utility is being operated efficiently and effectively for the benefit of all.

Summary

The water industry today is facing momentous challenges. It must: [1] recognize and eliminate the many deficiencies now prevalent in the existing systems; [2] secure qualified management; and [3] obtain realistic rate schedules that will permit the industry to meet the challenges.

Today this country is experiencing an unusually large population increase. By 1975, about 60,000,000 new citizens will need all the services most of us take for granted, including water service. To meet this additional challenge, the water industry must make plans now and put them into effect as soon as possible. All these challenges can be met if present problems are recognized and tackled aggressively.

Reference

1. Porges, Ralph. Summary of 1955 USPHS Survey of Treatment Facilities in Communities of 25,000 and Over. *Jour. AWWA*, **49**:1567 (Dec. 1951).

Effect of Natural Fluorides on Caries Incidence in Three Georgia Cities

In the February 1959 issue of *Public Health Reports*, an article by F. D. Lewis and E. C. Leatherwood reports the results of a USPHS study instituted at the request of Savannah, Ga. The tests were to determine whether a significant reduction in the caries attack rate would be derived from an adjustment of Savannah's natural fluoride concentration of 0.38 ppm to the approved level of about twice that amount. The other two towns included in the study were Macon and Moultrie.

The dental survey, which included 9,301 continuously resident, white schoolchildren between the ages of 6 and 15 years, was conducted in order to determine the effect of different concentrations of natural fluoride in the water systems upon the rate of dental decay.

The natural fluoride concentrations were approximately 0.11 ppm for Macon, 0.38 ppm for Savannah, and 0.75 ppm for Moultrie. The mean maximum annual temperature for these cities was 77.6°F, 76.6°F, and 80.0°F, respectively.

On a percentage basis, Moultrie had about twice as many caries-free children as Savannah and more than two and one-half times as many as Macon; the decayed-filled rates for primary teeth were slightly lower in Moultrie than in the other two communities.

The decayed, missing, or filled (DMF) rate for permanent teeth per child was 4.64 in Macon, 2.99 in Savannah, and 1.82 in Moultrie. Moultrie's DMF rate was 60.8 per cent lower than Macon's and 39.1 per cent lower than Savannah's; Savannah's was 35.6 per cent lower than Macon's.

Federal Trade Commission Decision on 'Evis Water Conditioner' Claims

A news release, issued on Apr. 3, 1959, by the Office of Information of the Federal Trade Commission, Washington, D.C., summarizing an FTC decision on a complaint against Evis Mfg. Co. (In an initial decision in April 1956, the hearing examiner had dismissed the complaint. The FTC counsel then appealed to the commission, which remanded the case to the examiner for the reception of evidence concerning further scientific tests of the "Evis Water Conditioner." The examiner, after taking such evidence, filed a second decision in June 1958, again dismissing the complaint. He based his holding on the ground that the disposition of the proceeding must be controlled by the legal principle that, when conflicting evidence is in such a state of balance that substantial doubt exists as to the conclusions to be drawn therefrom, the burden of proof has not been sustained. The FTC counsel appealed to the commission once more; the result of this appeal is set forth below.)

THE Federal Trade Commission has ordered Evis Manufacturing Co., San Francisco, Calif., to stop falsely claiming that its "Evis Water Conditioner" has any beneficial effect on water. The scientific evidence and testimony in support of the charges clearly outweigh the testimony given by the concern's user witnesses, the FTC ruled.

Accordingly, it granted an appeal by its trial counsel, and vacated a hearing examiner's initial decision, filed Jun. 30, 1958, which would have dismissed the Feb. 5, 1954, complaint for failure of proof.

The FTC's opinion, by Commissioner Sigurd Anderson, describes the device as "an oversized pipe coupling with an interior crosspost integrally cast in place. It is made of cast iron or bronze or similar metals and coated inside and out with zinc galvanizing. The device is intended to be fitted into water systems for the purpose of beneficially treating and conditioning water."

Evis and its vice-president, Arthur N. Wells, were ordered to discontinue more than a score of false claims. Specifically, they are forbidden to represent that the "Evis Water Conditioner":

Has a catalytic effect on water or changes its physical behavior

Will solve hard-water problems, make hard water soft, or cause hard water to feel, taste, or act softer

Will remove or reduce unpleasant odors or flavors from water

Will make water taste better or improve the taste of beverages or food

Will save soap and reduce the cost of heating water

Will eliminate or reduce harshness of water to hands

Will cause dishes or glassware to dry without leaving water stains

Will remove grease, prevent or remove scale, and improve the action of chemicals used for water softening

Will prevent, reduce, or eliminate scum, rust stains, and corrosion, or retard pitting of metal

Will leach out alkali and salts in soil, and reduce the amount of water required for agricultural irrigation

Will improve the soil's texture or structure, and the growth or production of agricultural or orchard products.

Weight of Evidence

The commission pointed out that the record indicates that Evis' counsel admitted failure of the Evis unit in 3,000 installations. More important, the opinion continued, is the testimony and other evidence by engineering and scientific experts that the device will neither alter the characteristics of water nor produce the claimed beneficial effects. The experts' testimony conflicted with that of users of the device who appeared for the company.

"The hearing examiner," the opinion stated,

> has given little weight to the evidence received in support of the complaint. In many instances of tests or studies being made, he questions the results because of the doubt raised on cross examination about whether the Evis unit was properly installed. Apparently, not all of the experimenters followed instructions for installation in every particular. This may have a bearing on the fairness of the tests in some cases, but we do not think that a substantial part of the scientific evidence should be largely discounted for such a reason. Manufacturers' instructions should be followed, of course, to achieve the results claimed for a product, but in this case the "instructions" have varied from time to time and apparently are not all contained in any one document. A step indicated as essential in one instruction sheet, for example, may not even be mentioned in another. Under such circumstances, the failure to follow the omitted instruction should not necessarily put doubt on the experiment. . . .
>
> The scientific evidence and testimony . . . supports the allegations of the complaint, and it is substantial. This evidence is strong, clear, and persuasive. Taken all together, it would be of compelling significance under any circumstances. Here we have the opinions of men of broad training and experience, which opinions were based on studies in the laboratory and field, as well as upon general experience. Their qualifications generally are beyond challenge.

For example, the opinion noted, Dr. James I. Hoffman of the National Bureau of Standards testified that, based on his scientific knowledge and his experience with the device, it could have no effect on water. The hearing examiner, in his initial decision, held that the probative value of this testimony was lessened because the witness did not preclude the possibility, at some future date, of a change being effected in the physical behavior of water, in a water system, by contact at the interface with a specially processed metal. The examiner held that the claimed change in the behavior of water by passage through the device had not been proved *impossible*. Disagreeing, the commission said:

> This, we think, is much too high a standard of proof. Dr. Hoffman has clearly testified that the "Evis Water Conditioner" will not beneficially affect water. To the extent that he may have admitted the possibility of any claimed effect, it was under the qualification that it would be beyond his comprehension if

it could be done. He testified on the basis of present-day knowledge and his experience with the Evis device. In our view, his testimony should not suffer merely because, as a man of science, he admits the possibility of an occurrence, however remote. . . .

It is obvious that [the FTC] counsel supporting the complaint has made a showing with reliable, substantial, and probative evidence that the "Evis Water Conditioner" will not perform as claimed. We do not think that counsel has shown it is impossible for the Evis unit to produce beneficial results, nor do we think such proof, if it could ever be made in a case of this nature, is necessary. Not all of the evidence in support of the complaint is strong; not all of it is free from defects. Taken in its entirety, however, it covers the views of many scientific and engineering experts in the various related fields and it is almost wholly adverse to the "Evis Water Conditioner." The views expressed were not simply opinions based on general experience alone. In almost every case, experiments or tests were performed. Some were in the laboratory and some involved practical installations.

Turning to the respondents' (Evis) evidence, the commission stated that, although they introduced some of a scientific nature, "it appears to be of little, if any, significance." The opinion continued:

In any event, respondents do not press their cause on the basis of any scientific evidence. They apparently concede that the effect resulting in the benefits to be derived from the use of their device, if any, is a scientific mystery. Respondents' evidence is largely that of the user testimony and the related exhibits.

An examination of this evidence shows that a number of users, including operating engineers and others, believed that they obtained beneficial results from the use of the "Evis Water Conditioner." While a number of the witnesses testified about observing results in parallel practical experiments, it nevertheless appears that the observations were not of tests under scientifically controlled conditions. Any one of a number of factors not connected with the "Evis Water Conditioner" could have caused any differences which may have been noted. This evidence, while relevant, must be considered and weighed in the light of all the surrounding circumstances. In some cases, such testimony may be more important than in others, particularly where there is scientific evidence of considerable weight on both sides of the question. . . . That is not the situation in this proceeding. The scientific evidence in the record almost entirely supports the allegations of the complaint. The user evidence, in these circumstances, is of relatively little value.

Joint Administration of Water and Sewage Facilities

Committee Report

A report of Committee 4430 M—Joint Administration of Water and Sewage Facilities, submitted by Leonard N. Thompson (Co-Chairman), Gen. Mgr., Water Dept., St. Paul, Minn., and Robert J. McLeod (Co-Chairman), Deputy Chief Engr., Washington Suburban San. Com., Hyattsville, Md. Other members of the committee were: Sidney S. Anthony, Albert E. Berry, Earl Devendorf, Oscar R. Elting, Harold F. Gray, John W. McFarland, John W. Pray, Hal F. Smith, Elwood J. Umbenhauer, C. F. Wertz, and D. McGregor Williams.

THE Committee on Joint Administration of Water and Sewage Facilities (4430 M) made its first report in 1946. That report was concerned primarily with the nature, amount, and bases of sewer service charges, particularly as they were administered by water departments. The present study grew out of an increasing interest in and tendency toward a more complete and closer administration between water and sewer departments, evidenced by the number and nature of the inquiries that have been directed to the headquarters of AWWA. These inquiries have indicated that more and more cities either have turned to some form of joint administration, have it under consideration, or feel that they should. With joint administration have come new problems and the need for a review of present practices.*

* Although it is recognized that some privately owned water utilities also collect sewer service charges for municipalities on a contract basis, this aspect of joint administration was not covered in the committee's survey.

Present Practices

To determine the extent of present-day practices, and to obtain answers to the many questions and attempts to evaluate these practices, a questionnaire was sent to approximately 1,000 cities with a population of more than 10,000. The questionnaire was divided under three principal headings, covering general information, administration, and financing. Replies were received from 437 cities, a fairly representative sample. This is probably indicative of the general interest in these problems. A large amount of information, mostly statistical, was obtained. Replies to the survey cannot, it is believed, be taken as necessarily representing in all instances the individual's best judgment or his approval of the practice he follows. Some, and possibly many, persons may be working under local conditions or restrictions prescribed by law, making it difficult, impractical, or impossible to follow or adopt known or proposed better practices, or perhaps even to go by the administrator's own judgment. It may be assumed, however, that where

TABLE 1

Results of Questionnaire on Joint Administration of Water and Sewage Facilities

Questions	Number Replies Recd.	Yes	No	% Yes*
General				
1. Are water and sewerage systems under one administration head?	434	196	238	45
2. If not, is such being considered?	224	20	204	8
3. If under joint administration, to what extent is sewerage system included?	187			
a. complete		53		28
b. disposal plant only		11		6
c. sanitary sewers only		6		3
d. storm sewers only		1		1
e. billing and collection only		25		13
f. not complete but various combination of above		91		49
4. How was joint administration authorized?	211			
a. state or provincial special legislation		19		9
b. state or provincial enabling legislation		4		2
c. local legislation		120		57
d. administrative authority		50		24
e. federal authority		1		1
f. more than one authority		17		8
5. Does water system serve outside areas?	407	314	93	77
Does sewer system serve outside areas?	374	190	184	51
Administrative				
1. Does city have a sewer service charge?	417	247	170	59
2. If not, is it being considered?	157	59	98	38
3. Is charge made for billing and collection?	292	171	121	58
4. Is service charge on water bill?	300	215	85	71
5. Who determines the charge?	259			
a. water department		60		23
b. sewer department		42		16
c. jointly		15		6
d. others		142		55
6. Can water be shut off to enforce rules or payment?	319	254	65	80
7. Is service charge a lien on property?	294	176	118	60
8. What is authority for service charge?	267			
a. state and province		19		7
b. local		215		81
c. others		11		4
d. federal		1		1
e. state and local		21		8
9. Was water dept. compelled to collect sewer charge?	280	188	92	67
Financial				
1. Are water and sewage funds kept separately?	367	323	44	88
2. Can water funds be used for the sewage system?	363	92	271	25
3. Can service charge be used for other than operating expenses —that is, for new construction?	264	197	67	75
4. Can sewer service charge be collected for new or anticipated new construction?	257	105	152	41

* Approximate percentages given.

TABLE 1—*Results of Questionnaire (contd.)*

Questions	Number Replies Recd.	Yes	No	% Yes*
5. Source of funds for maintenance and operation costs?				
a. Service charge	219			
for storm sewers only		0		0
for sanitary sewers only		9		4
for trunk sewers only		0		0
for disposal plant only		28		13
for various combinations		182		83
b. Taxes	262			
for storm sewers only		71		27
for sanitary sewers only		4		2
for trunk sewers only		0		0
for disposal plant only		3		1
for various combinations		184		70
6. Source of funds for construction				
a. Service charges	186			
for storm sewers only		2		1
for sanitary sewers only		12		6
for trunk sewers only		2		1
for disposal plant only		31		17
for various combinations		117		63
for any one or all		22		12
b. Taxes	263			
for storm sewers only		33		12
for sanitary sewers only		6		2
for trunk sewers only		1		1
for disposal plant only		2		1
for any one or all		108		40
for various combinations		113		43

* Approximate percentages given.

a predominant use of any one procedure is found, this is some indication, at least, of agreement on the value of the procedure.

The rapid development of both urban and suburban areas and the rapid growth of industrial strength have brought with them a growing realization that if the future of the United States is to be safeguarded, positive steps must be taken to protect, as well as conserve, its water resources. National, state, provincial, and local authorities have shown increasing concern for water resources, often to the extent of legislating its conservation and protection. This concern has influenced the rapid increase in the construction of new, or the enlargement of existing, sewage disposal or treatment plants to protect present and future water supplies. Sewer departments have historically been tax supported, and in many cities the department's budget is being strained by the resulting additional financial burden.

The low legal limitation on the bonded indebtedness existent in many areas, together with a desire to relieve real estate of its already heavy tax burdens, has caused many cities to

seek other methods of raising necessary funds. Because Americans have become so tax conscious, there has been a growing tendency to pull away from the practice of raising funds for any and all purposes by the common frontage tax method or by general tax levies. Instead, the burden for the operation and upkeep of special services, and, often, for all or a part of the capital costs, is put directly on those who use or are benefited by such services. In particular, this has been true with sewage systems and sewage treatment plants. The service charge has provided a logical and generally acceptable means of raising funds. For years, many water departments have been given the responsibility of billing and collecting service charges on behalf of and for certain sewage system expenses. It would appear that not only have the popularity and use of the service charge increased, but likewise the purposes for which it is used have increased, resulting in higher charges that appear as a large percentage of the water bill. It should be pointed out that the collection of an extremely high service charge, or one computed as a percentage of the water bill, could be very undesirable for the water department.

Questionnaire Analysis

An analysis of the replies (Table 1) shows that many of the answers do not clearly fall into one category or another. The term "complete administration" is only relative and can be taken as referring to any level, from top management only, to the complete control of all activities and functions from the top to the lowest level. A clear-cut distinction between joint administration and joint operation was often difficult to determine; however, between these extremes there can be, and apparently are, many degrees of joint effort.

Joint Control

The returns indicate that 211 of the 437 cities replying have the authority to bring about joint administration; that 196 cities have availed themselves of that authority; and that 20 more are considering it. The authority was by special and enabling legislation in 23 cities; by administrative authority in 50; by local legislation in 120; and by federal authority in one. A total of 187 replies to the question concerning degree of joint control indicated that it approximated the following pattern:

1. A total of 53 cities reported complete control.
2. In 11 cities, control was over the disposal plant only, with 60 cities controlling the disposal plant and other functions.
3. In 6 cities, control was over sanitary sewers only, with 72 cities controlling sanitary sewers and other functions.
4. In 25 cities, control was over service charge only, with 67 cities controlling service charge and other functions.
5. In only one city was the control over storm sewers only, with 26 cities controlling storm sewers in conjunction with another function.

The 1946 survey indicated that approximately 200 cities were using a sewer service charge. Presently, it was found that 247 cities have a sewer service charge and that an additional 59 are considering it, indicating that the trend toward this practice may not have been as fast as expected. It is

believed, however, that the degree of joint operation has increased much faster. In 215 cities, the billing of sewer services is included with the water charges on the water bills; in only 171 cities is a charge made for this billing service. It was interesting to note that in only 117, or approximately half the cities, did the water department or sewer department determine the amount of the service charge. In 60 per cent of these cities, the charge was a lien against the property; water could be shut off to enforce payment in approximately 80 per cent. In 76 per cent of these cities, the water department apparently had no choice but to collect the service charge, which in the great majority of cases was authorized by local authority.

Sources of Revenue

The extended demand for sewer systems and disposal plants, historically without revenue-producing means or facilities for either extension or operation, can easily make water revenues a tempting source of assistance and a means of obtaining needed funds. In one instance, the operation of a sewer department laboratory, with all attendant cost, was initially transferred to the water department. Later, the disposal plant was transferred, and finally the debt charges, operation, and maintenance of the sewers. This situation was eventually corrected by the establishment of a very sizable sewer rental charge to take care of both debt and operating costs.

As to the source of funds for the operation and maintenance of sewage facilities, out of 481 replies to the question, 219 indicated use of the service charge and 262 use of tax funds. For construction of these facilities, out of 449 cities replying, 186 indicated use of the service charge and 263 use of tax funds. Predominantly, both storm sewers and disposal plants are built, maintained, and operated by tax funds; 197 out of 264 indicated that the service charge could be used for construction.

For 60 cities reporting, the service charge paid an average of 85 per cent of the maintenance and operating costs of the sanitary and trunk sewers and disposal plant, and in nine cities an average of 72 per cent of the maintenance and operating costs of the storm sewers. Eight cities reported 100 per cent of the maintenance and operating charges paid by taxes, 44 reporting that the service charge averaged from 75 per cent to 80 per cent of the construction costs. One city reported that the service charge is used as a contribution for preliminary design as well as construction, operation, and maintenance costs. In one state, the law requires the construction of a disposal plant with each new sewage system. It was stated that the costs were beyond the borrowing power of many small cities. As a result, some cities sought to build up a reserve fund by imposing a service charge collectible with the water bill several years in advance of construction. Out of 257 replies, 105 indicated that the sewer service charge could be earmarked for future construction.

Outside Services

The rapid growth of suburban areas has produced serious problems relating to the provision of public sewers, water, and other community facilities and services. In many instances, cities and states are recognizing these problems and are turning their attention

to the creation of metropolitan authorities for the orderly planning and development of such areas.

In the last 10–15 years in particular, many families have moved from city to suburban areas to get away from high taxes, only to find in a relatively short time, as the suburbs develop, that the need for water, sewer, fire, and police protection, with all the many public services rendered in a large city, has become a necessity. Also, there is a growing tendency for industry to spread out. When large industries move to suburban areas, they usually take many families with them. These factors result in the installation of the needed facilities, or in annexation or extension of city services to the outside area.

The topography of areas adjacent to the city, which can cause the drainage of much of the runoff into the city, and the increasing sanitary problems because of nonsewered areas, have in many instances made the problems of the suburbs also the problems of the city. Urban growth and metropolitan development have created problems that transcend the boundary lines of local governmental units. Thousands of private wells and septic tanks in suburban areas close to a public water supply can be a serious threat to public health. Septic tanks and soil absorption systems have no place in a well developed area. They are a matter of concern to both the water and sewer departments of a city. Resulting problems call for cooperative effort, the creation of metropolitan administration and technically sound control, and ordinances from a centralized water and sewerage facility.

The committee inquired about the number of cities that now supply water and sewer service to adjoining areas. Of 407 cities that replied, 314 are presently giving outside water service; 190 out of 384 cities are presently providing outside sewer service. Utility services to such areas present problems, because the city is not only giving service to the suburban area but also may be making available a plant investment toward which the areas have contributed nothing. Furthermore, the added load generally accelerates the need for additional capital outlay. Because the city supplier probably has no authority to tax property beyond the city limits, the only way to recover the capital costs involved is either to increase the service charges made to customers outside the city or to exact a direction contribution, or both methods.

Conclusions

The committee feels that water supply and waste disposal are both indispensable services to an expanding population. Many of the administrative and operating functions of the two services are in general so parallel that some form of joint operation is both economical and highly desirable. As one member of the committee expressed it, the regulation of the entire cycle of water should be considered a municipal function, with sewage regarded only as used water.

In smaller cities it would seem that complete administrative and operational functions can most easily and advantageously be carried on under one head. In larger cities, although the extent of the activities might well dictate certain separate functional operations or separate bureaus, there still can be distinct advantages with joint or top level control over such factors

as design, engineering, and supervisory and office personnel. It would appear that water departments not presently aware of the advantages, should recognize and concern themselves with the possibility of partial or complete joint controls, either administratively or functionally. Joint functioning does not of itself present particularly difficult problems of operation, and the identity of each department can and preferably should be maintained. The use or diversion of water department funds for purposes other than those pertaining to the department should be most carefully avoided in any proposed joint operation.

A sewer service charge is deemed a very proper means whereby funds can be collected for sewage system purposes. Billing and collection of such a charge by the water department present an economical and practicable procedure that has proved satisfactory to both the consumer and the city. It seems highly desirable, in the interests of the water department, that the water consumer be kept cognizant of the fact that the sewer service charge, which may appear on the water bill and be collected by the water department, is not a part of the water bill. It is a courtesy service rendered for and on behalf of the sewer department in the interest of economy.

The billing and collection of a sewer service charge is a degree of joint administration. It should carry with it authority to establish rules and regulations to accomplish the purpose and to enforce collection. It seems most logical that a water department be reimbursed for all expenses incurred from such billing and collection, as well as for administrative costs for any service rendered.

There appears to be no argument against the collection of a rental or service charge from the users of sewer facilities to cover the costs of maintenance and operation. The main interceptor and trunk line sewers are so closely related to a disposal plant that a sewer service charge seems to be justified for their maintenance and operation. There was doubt, however, in the minds of some as to the extent to which such revenue should be used for construction costs or for the amortization of outstanding bonds, either for new sewers or a sewage treatment plant. It may well be argued that a sewer system and a sewage treatment plant are beneficial to all properties, vacant or developed, and because property values are increased if these services are available, whether used or not, at least a substantial part of the capital cost of the services can more equitably be paid by tax levy against all property. The capital costs of sewer laterals and storm sewers would properly seem to be recoverable by a tax or by a special, or spread, assessment against the properties directly affected, with maintenance cost recoverable through the service charge.

The majority of the committee felt that a service charge could properly be used for both maintenance and operation and capital debts. A few members felt that the use of a service charge for a small working fund and minor capital betterment was often advisable, but that major improvements were better financed through the issuance of bonds. It was the general belief that the use of a service charge, or any substantial part thereof, for the purpose of building up a fund for future construction was not advisable. It is certain that if any part

of service funds are set aside for either a sinking fund reserve or for anticipated new construction, they should be protected against use for any other purpose. The ever present danger in the accumulation of a sizable fund created by a service charge is the temptation to exploit it for purposes for which it was not designed, perhaps even for what might be termed luxury items, while neglecting important utility needs.

Service to outside areas is a logical outgrowth of urban and suburban growth. A city and its suburbs are parts of an economic unit, each dependent upon the other. It should be realized, however, that as the suburban areas develop, sooner or later they will place a strain upon the central facilities and require capital investments. Those responsible for such an expansion must be prepared to shoulder their proportionate share of the expense.

The committee appreciates that there can be no fixed set of rules applied to all cities or all conditions. Modification of any practice suggested as being good or generally accepted may be necessary in many instances to meet local conditions or requirements.

Revision of Steel Tank Standard (AWWA D100)

On Jan. 26, 1959, the AWWA Board of Directors approved a number of minor corrections and changes in AWWA D100–55—Standard for Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage. The sections affected are: 1.2, 1.5, 1.6, 2.12 (new), 3.2.2, 3.2.3, 3.3.2, 3.3.5, 3.5.1, 3.15.2, 8.4, 11.3, and A1. The standard has been redesignated AWWA D100–59.

Influence of Water Composition on the Corrosion of Steel

George B. Hatch and Owen Rice

A contribution to the Journal by George B. Hatch, Corrosion Research Group Leader, Chem. Research & Development, and Owen Rice, Vice-Pres., Industrial Chemicals, both of Calgon Co. (division of Hagan Chemicals & Controls Inc.), Pittsburgh, Pa.

OCCASIONALLY water supplies are found to be relatively noncorrosive to iron and steel. Some of these supplies are hard, scale-forming waters that form protective calcareous deposits on metal surfaces and thus isolate them from the otherwise corrosive environment. Other waters are practically devoid of dissolved oxygen and, therefore, lack the capacity to cause appreciable corrosion in the neutral pH range. A small group of waters remains which appears to defy the usual criteria of corrosivity. Waters of this type contain enough dissolved oxygen to cause corrosion and have no scale-forming capacity to stifle it, but they nevertheless attack iron and steel at an extremely low rate.

The chief analytical characteristics of the noncorrosive waters of the latter type are a low dissolved-solids content and an absence of appreciable anions other than bicarbonate. The presence of traces of some unknown natural inhibitor, such as have been found in relation to copper (*1*), does not appear likely; synthetic waters of comparable compositions show a similar low corrosivity. Thus, it appears that the required conditions for this relative noncorrosivity should be amenable to laboratory investigation in synthetic waters.

Relatively simple systems were chosen for the initial investigation. The influence of chloride, sulfate, bicarbonate, and mixtures of chloride with bicarbonate and sulfate with bicarbonate on the corrosion of steel was investigated. The cation was restricted to calcium.

Experimental Method

The corrosion tests were made in small-volume batches, as previously described (*2*). The test panels consisted of 1½-in. square, 24 gage, cold-rolled, immersed in 1-liter portions of the waters tested. Agitation was provided by lateral movement of the panels back and forth through the water over a distance of 2 in. at a rate of 32 cycles per minute. The tests were conducted in a constant-temperature air bath maintained at 35 ± 0.1°C. The duration of the tests was 5 days.

Prior to the tests the steel panels were thoroughly cleaned in an alkaline cleaner, thoroughly rinsed first with tap water and then distilled water, and towel-dried. The panels were pickled in 6*N* hydrochloric acid which contained 0.1 per cent di-*n*-butylthiourea as inhibitor at the conclusion of the test. Pickling blanks were determined and the observed weight losses were

corrected accordingly. Weight loss was used as the criterion for determining the corrosion rate.

Analytical reagent grade chemicals and distilled water (with a conductance of 1.5–2.5 micromhos at 25°C) were used for all solutions. Stock calcium bicarbonate solutions were prepared by passage of carbon dioxide through suspensions of calcium carbonate in distilled water.

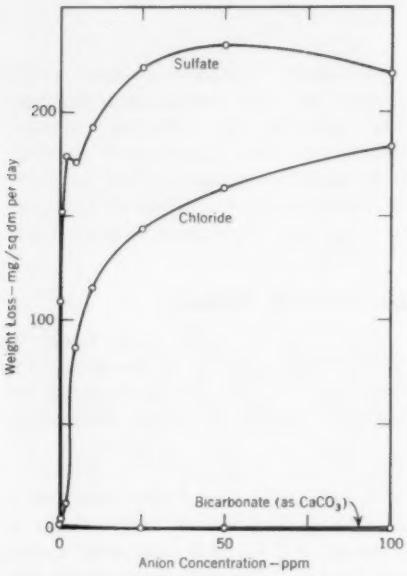

Fig. 1. Influence of Sulfate, Chloride, and Bicarbonate on the Corrosion of Steel

Data are for agitated tests at 35°C. The cation used was calcium.

Results

The influences of calcium bicarbonate, calcium chloride, and calcium sulfate on the corrosivity of distilled water to steel were individually investigated. The results obtained at anion concentrations of up to 100 ppm are shown in Fig. 1. Several features of these data are noteworthy. First, the distilled water was only very slightly corrosive under the conditions of exposure. Second, the addition of bicarbonate to the distilled water reduced the corrosion to an even lower level. Third, the corrosive attack was very sensitive to chloride even at very low concentration levels. Finally, the sensitivity of corrosion to sulfate is even more pronounced than to chloride.

The influence of very low concentrations of chloride and sulfate on the corrosive attack is shown more clearly in Fig. 2. This is a replot on an expanded concentration scale of the data from Fig. 1 for low anion concentrations (0–10 ppm). The slight initial lag before the sharp rise in the curve for chloride is more obvious in this figure than in the previous one. A similar initial lag, although restricted to a considerably lower anion concentration, is indicated in the curve for the sulfate.

The strips exposed to distilled water quite rapidly assumed a faint yellow discoloration after which there was little change in appearance for the duration of the tests. The appearance suggested the presence of a hydrous ferric oxide film. The visibility of the hydrous oxide suggests that the film was rather thick in comparison with the usual protective oxide film. Further evidence of the presence of such an oxide film was afforded by the rather noble potential (of the order of −0.2 v with respect to saturated calomel) of the bare steel electrode of a differential aeration cell in distilled water. It thus appears that the formation of a protective oxide film was responsible for the relative noncorrosivity of the distilled water in these tests.

The formation of a protective oxide film in the distilled water indicates that the dissolved oxygen exerted an inhibi-

tive action. Such an inhibitive mechanism requires an adequate supply of dissolved oxygen to the metal surface. The protection of steel in distilled water requires just such a supply. This is shown by the results in quiescent distilled water where the rather slow process of diffusion had to be relied upon to supply oxygen to the metal surface. The corrosion rate of steel under such conditions was found to be 26 mg per square decimeter (sq dm) per day—roughly 13 times its rate with agitation.

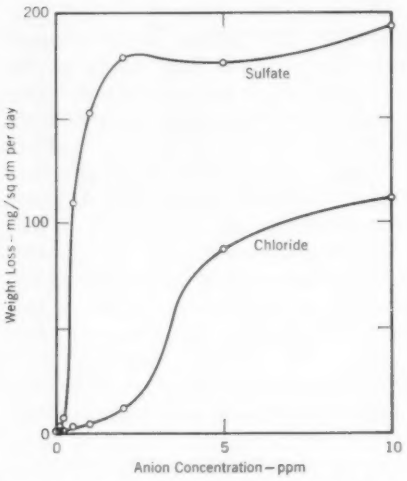

Fig. 2. Influence of Low Chloride and Sulfate Concentrations on the Corrosion of Steel

Data are for agitated tests at 35°C. The cation used was calcium.

The corrosion rates in the calcium bicarbonate solutions were even lower than in distilled water. In fact, the weight losses at all bicarbonate levels investigated were so low that they approached the accuracy limits of the weighings. The inhibition of corrosion in the bicarbonate solutions appears to have been the result of a protective hydrous oxide film. This film appears to have been somewhat thinner than it was in distilled water, as no surface discoloration was observed in the bicarbonate waters. The lower corrosion rates in the bicarbonate solutions may indicate a reduction of the initial corrosive attack, which, in distilled water, led to the rather rapid surface discoloration.

The presence of chloride or sulfate either disrupts or prevents formation of a protective oxide film such as that formed in distilled water. Instead, a heavy rust layer forms, which appears definitely nonprotective. Precipitation of the hydrous oxide in the presence of chloride or sulfate apparently occurs too late to stifle the rust formation. This may be a result of the greater potential acidity at the anodic areas in the presence of the anions of strong acids.

Sulfate shows a more pronounced tendency to interfere with the protective film than does chloride. This suggests either a great disruption of the oxide film or the formation of a less protective oxide coating. The latter appears more probable, as chloride generally has a much greater tendency to penetrate oxide films than does sulfate.

The type of corrosion that took place in distilled water and in the presence of calcium chloride or calcium sulfate was very uniform; there was no indication of pitting or tuberculation. The attack in the calcium bicarbonate solutions was too slight to alter the appearance of the panels.

The pH of the solutions was not adjusted prior to the tests because of the sensitivity of corrosivity to very low electrolyte concentrations. In fact, initial pH determinations were restricted to duplicates of the solutions

used in the corrosion tests in order to avoid possible contamination (for example, from the salt bridge). The pH of the distilled water used in the tests ranged from 4.8 to 5.9. In the course of the tests it tended to approach a value of from 4.9 to 5.1. This apparently was an equilibrium value with respect to the carbon dioxide content of the exposure atmosphere. The initial pH of the bicarbonate-treated waters was 6.5–6.9. This value rose quite rapidly to 7.8–8.0 at 25 ppm calcium carbonate and 8.2–8.4 at higher bicarbonate concentrations. Here, again, the pH values appear to reflect equilibrium with the atmospheric carbon dioxide. The calcium chloride did not significantly affect the pH of the distilled water either initially or at the conclusion of the test. Calcium sulfate raised the initial pH by approximately 0.2 for 10 ppm sulfate and by 0.9 for 100 ppm.

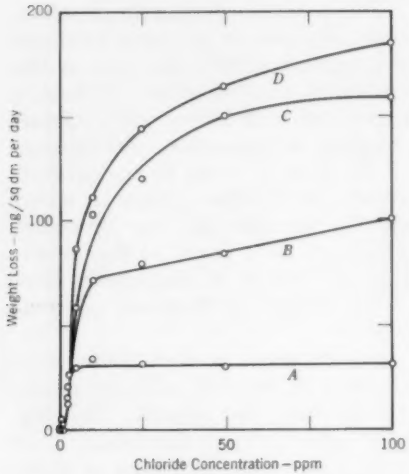

Fig. 3. Influence of Chloride on Steel Corrosion at Various Bicarbonate Concentrations

Curves A, B, C, *and* D *represent results at bicarbonate concentrations of 100, 50, 25, and 0 ppm, respectively. The data are for agitated tests at 35°C. The cation used was calcium.*

Weight loss variation between duplicate runs was quite marked in the low chloride and sulfate ranges where the corrosion rate increased very rapidly with very slight increases in chloride or sulfate concentrations. In this critical range weight losses at times were very low and at others quite high; occasionally the attack would proceed very slowly in the early stages of the test, after which rust would form quite rapidly. In this range a breakdown of the protective oxide layer appears to start. This layer is quite effective for distilled water, but it offers little protection against chloride or sulfate. Slight variations in its character might be expected to cause marked differences in the rate of attack in this critical borderline sulfate or chloride range. The variation decreased progressively as the critical range was exceeded and became essentially constant for concentrations of 25 ppm or more. The maximum deviation from the mean in the latter range was 10 per cent for the chloride system and 15 per cent for the sulfate. In view of the poorer reproducibility of the sulfate systems, the average of at least six runs was taken for the data reported; the average of at least three was taken for the chloride data.

There was no correlation between these variations in weight loss and those previously noted with respect to pH. Such a correlation would not be expected, as the pH variations were all within the "neutral zone" (*3*). Variations within this zone have not been found to alter appreciably the attack on steel (*3*).

Chloride–Calcium Bicarbonate Systems

The influence of calcium chloride on the corrosion of steel in the presence of calcium bicarbonate was investigated at several bicarbonate levels. The data are given in Fig. 3. These data show that the corrosion was reduced by the bicarbonate. The extent of the reduction is dependent on the bicarbonate level. A concentration of 25 ppm (as $CaCO_3$) causes only a slight reduction, 50 ppm is considerably more effective, and 100 ppm provides a fair degree of inhibition. In addition, the bicarbonate tends to reduce the susceptibility of the attack to chloride concentration. A concentration of 25 ppm reduces this susceptibility only slightly. It suffices only to provide a slight lag in the rate of increase in weight loss as the chloride concentration is raised. A concentration of 50 ppm (as $CaCO_3$) bicarbonate has a more marked influence, particularly at chloride concentrations of more than 10 ppm; subsequent increases in the chloride concentration produce only a gradual increase in the corrosion rate. Chloride concentrations in the range of 2–100 ppm have little influence on the amount of attack at the 100-ppm bicarbonate (as $CaCO_3$) level.

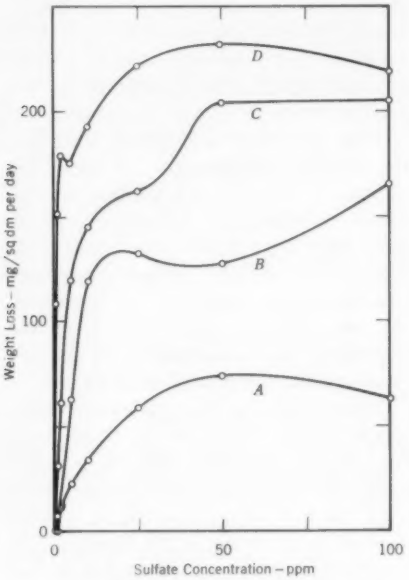

Fig. 4. Influence of Sulfate on Steel Corrosion at Various Bicarbonate Concentrations

Curves A, B, C, *and* D *represent results at bicarbonate concentrations of 100, 50, 25, and 0 ppm, respectively. The data are for agitated tests at 35°C. The cation used was calcium.*

Sulfate–Calcium Bicarbonate Systems

The influence of calcium sulfate on the attack of steel also was investigated at several calcium bicarbonate levels. The data obtained in these tests are shown in Fig. 4. Here, again, the reduction in attack is to an extent dependent on the bicarbonate level. A concentration of 25 ppm (as $CaCO_3$) has only a slight effect; 50 and 100 ppm are progressively more effective. The data also indicate that calcium bicarbonate decreases the sensitivity of the attack to sulfate. As the bicarbonate level is raised, the attack rises more and more slowly with increases in sulfate concentration. The bicarbonate does not, however, prevent the attainment of rather high rates of attack in the sulfate system.

Calcium bicarbonate tends to counteract the influence of very low concentrations of sulfate somewhat more effectively than it does the influence of comparable chloride concentrations. At higher chloride and sulfate levels the situation is reversed; the bicarbonate

provides more effective protection against the action of chlorides than sulfates.

Weight losses were more erratic for the sulfate-bicarbonate systems (just as was the case for the sulfate and chloride alone). For this reason the average of at least six duplicate runs was the sulfate-bicarbonate systems (just as taken for the sulfate-bicarbonate values (Fig. 4) and three for the chloride-bicarbonate (Fig. 3).

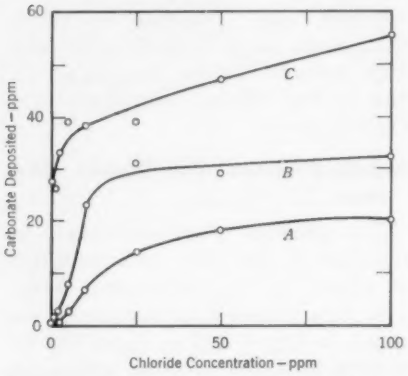

Fig. 5. Calcium Carbonate Deposition in Corrosion Tests in Chloride Solutions at Various Bicarbonate Concentrations

Curves A, B, *and* C *represent results at bicarbonate concentrations of 25, 50, and 100 ppm, respectively.*

Calcium Carbonate Deposition

The inhibition of the attack by the bicarbonate appears to be largely due to the formation of calcium carbonate deposits on the metal surfaces. Such deposits are quite obvious on the panels from the tests at the two higher bicarbonate levels (50 and 100 ppm $CaCO_3$), particularly at the higher chloride or sulfate concentrations at which the degree of inhibition involved is most pronounced.

The extent of the deposition for the chloride–bicarbonate series is shown in Fig. 5. The amount of calcium carbonate deposited at a given bicarbonate level increases as the calcium chloride concentration rises. The deposition at the 25 ppm bicarbonate level increases in a regular fashion as the calcium chloride concentration increases. The curves for the two higher bicarbonate levels (50 and 100 ppm $CaCO_3$) show an initial sharp rise followed by a more gradual increase in deposition as the calcium chloride content increases.

The carbonate deposition data for the sulfate-bicarbonate series are shown in Fig. 6. Deposition at the lower bicarbonate levels (25 and 50 ppm $CaCO_3$) initially rises quite rapidly as the calcium sulfate concentration increases, and then it levels off. At the 100-ppm ($CaCO_3$) level the deposition increases steadily as the calcium sulfate concentration is raised.

Most of the calcium carbonate deposition which occurred in these tests took place on the steel test strips. Only at the highest bicarbonate level (100 ppm $CaCO_3$) was there notable deposit on the walls of the beakers. At the 25-ppm level only rather heavy rust was visible on the panels when chloride or sulfate was present. Apparently the calcium carbonate deposited was interspersed in these rust layers. At the 50- and 100-ppm levels, the panels showed areas that were not appreciably attacked. When chloride or sulfate was involved these areas were covered with a visible calcium carbonate film. This film was broken in spots by rust tubercles. There was a marked tendency for the growth of rather voluminous rust deposits near the edges of these panels.

Type of Attack

The corrosion that occurred in the water treated with chloride or sulfate alone was general as noted earlier. Corrosion that occurred in the bicarbonate-treated systems tended to be localized (except at the very low sulfate and chloride levels where attack was insufficient to alter the appearance of the metal surfaces). This localization of attack increased as the inhibitive action of the bicarbonate developed. Attack at the 25-ppm carbonate level

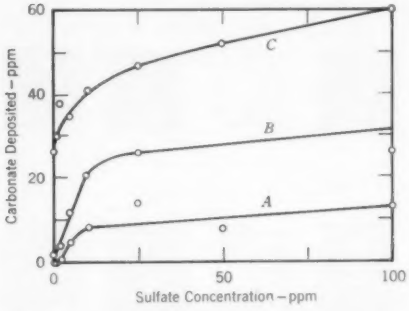

Fig. 6. Calcium Carbonate Deposition in Corrosion Tests in Sulfate Solutions at Various Bicarbonate Concentrations

Curves A, B, *and* C *represent results at bicarbonate concentrations of 25, 50, and 100 ppm, respectively.*

remained essentially general; it became quite localized at the 50-ppm level in the presence of appreciable amounts of chloride or sulfate and even more so at 100 ppm. The localization of attack occurred under the rust deposits, both at the edges and at the scattered spots on the faces of the panels.

Typical sets of pickled panels from the chloride–bicarbonate and sulfate–bicarbonate series at the 100-ppm level are shown in Fig. 7. In each of these series, as soon as the chloride or sulfate concentration rises to a high enough level that noticeable corrosion occurs, the attack is concentrated in small local areas and the remainder of the surface is practically unaffected. The attacked areas are more numerous in the sulfate–bicarbonate series than in the chloride–bicarbonate; this indicates a higher level of corrosion in the former series.

It is apparent from Fig. 7 that the panel edges, including those around the hole, are somewhat more susceptible to attack in the bicarbonate-treated systems than are the bodies of the panels. As a result, the degree of inhibition on the bulk of the metal surface probably is somewhat greater than is indicated in tests with panels of small dimensions, in which edge effects are somewhat overemphasized. Quite scattered pitting can, however, escape detection on the relatively small face of the panels. The presence of the pitting-susceptible edges decreases the chance that such pitting may escape detection. A significant increase attack in the vicinity of the edges is not apparent in systems that do not promote localized attack—for example, the chloride and sulfate systems without bicarbonate.

Discussion

The low level of corrosivity of the distilled water in these tests perhaps appears contradictory to general experience with pure waters in this rather low pH range. Much of the experience with low-pH distillate is derived from condensate returns. Corrosion by this low-pH condensate is largely of an acidic, hydrogen evolution type; significant amounts of oxygen generally are not involved. Thus, the ready access of oxygen to the metal surface,

which appears to be requisite for the formation of the protective oxide film observed in the present tests, is not provided in the usual condensate return.

Further evidence of the low corrosivity of "pure" water under conditions of ready oxygen access is afforded by the low corrosion of steel panels in high-humidity (100 per cent) storage at 100°F with marked condensation. Rusting occurs only very slowly under such exposure, provided the panels have been previously well cleaned and thoroughly rinsed with high-quality distilled water, despite the practically continuous presence of condensed water on the metal surfaces. Access of oxygen to the surface is quite good under these conditions, as the diffusion path through the water to the metal surface is very short. Only a thin film of water can be retained on a vertical panel.

The extreme sensitivity of corrosivity to small amounts of chloride or humidity exposure results. When the panels were rinsed with Pittsburgh tap water (a predominantly sulfate water with moderate chloride content) after cleaning, they rusted quite rapidly in the humidity storage. The traces of sulfate and chloride left by the tap water apparently sufficed to accelerate the attack markedly.

The sensitivity of the corrosion rate to traces of sulfate also was the apparent cause for some very erratic results in early tests with distilled water. Corrosion rates of 5–100 mg/sq dm per day and greater were encountered in distilled water during these early tests. The high and erratic corrosion rates apparently resulted from adsorption of atmospheric sulfur dioxide and its subsequent oxidation to sulfate. The erratic, high rates of attack first disappeared when many of the mills in the area were closed by strike. Since the establishment of smoke control in the area, difficulties of this nature have not been encountered.

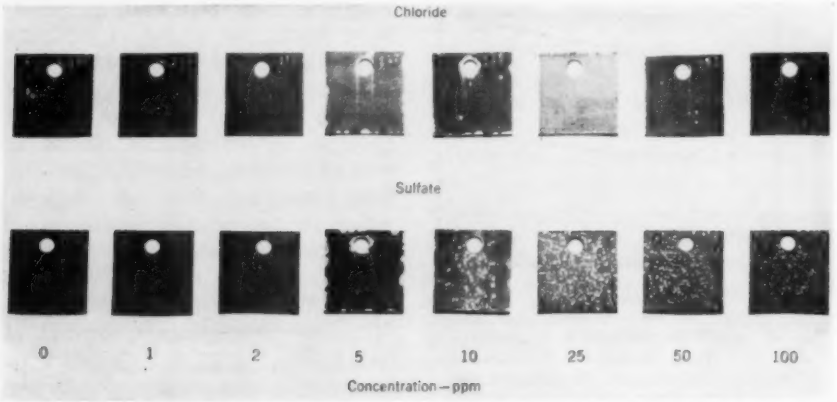

Fig. 7. Pickled Panels From Corrosion Tests in Bicarbonate Solutions at Various Chloride and Sulfate Concentrations

Bicarbonate solutions were 100 ppm $CaCO_3$. The upper and lower rows are from chloride and sulfate solutions, respectively.

The calcium carbonate deposition which occurred in the tests with the chloride–bicarbonate and sulfate–bicarbonate systems was concentrated on the metal plates. Only at the highest bicarbonate level (100 ppm $CaCO_3$) did appreciable deposition occur elsewhere. Ferric oxide is quite effective for the relief of calcium carbonate supersaturation (*4*), because it serves as nuclei for calcite deposition. The calcium carbonate deposits were concentrated on the relatively unattacked areas at the two higher bicarbonate levels (50 and 100 ppm $CaCO_3$) in these tests, however, rather than in the rust. This indicates that the deposition occurred on the cathodic areas as the result of electrochemical action—that is, the alkaline conditions developed at the cathodes apparently caused calcium carbonate to deposit in these areas—not as a result of the "catalytic" action of ferric oxide. The alkaline conditions of the cathodic areas also seem to have maintained the oxide film under the deposits in spite of the somewhat reduced access to oxygen; the calcium carbonate–covered areas do, at least, appear to have remained cathodic. The calcium carbonate layer might be expected to impede current flow to the cathodic areas and thus increase cathodic polarization.

The appearance of the panels at the higher bicarbonate levels definitely suggests accelerated corrosion at the attacked areas. There was, for example, a definite thinning of the plates where the attack concentrated on the panel edges, which suggests electrochemically accelerated corrosion. Apparently the calcium carbonate layer did not sufficiently impede current flow from the large cathodic areas to prevent rather heavy attack of the much smaller anodic areas. It would appear that a much heavier calcite deposit (a definite scale) would be necessary to control the localization of attack.

Acknowledgments

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Production of Bicarbonate Alkalinity

James Girand

A contribution to the Journal by James Girand, Chief Engr., Elizabethtown Water Co. Consolidated, Elizabeth, N.J.

BICARBONATE alkalinity is considered to be an important factor in alum coagulation (*1–4*). In addition, the calcium radical has been demonstrated to be an effective corrosion inhibitor (*5*). Consequently, the presence of bicarbonate alkalinity is essential for the best water treatment.

Chemistry of Coagulation

The commonly accepted chemical equation for alum coagulation as set forth in the standard textbooks is

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3\downarrow + 6CO_2.$$

As long as the water contains enough natural bicarbonate alkalinity to react with the alum according to the formula above, flocculation proceeds in a satisfactory manner. If there is not enough bicarbonate alkalinity present, flocculation proceeds either unsatisfactorily or not at all. There is frequently a low concentration of bicarbonate alkalinity during spring runoff, when the melting snow on frozen ground produces a surface water of extremely low chemical content. The condition is also aggravated if there is heavy turbidity in this runoff, because it necessitates an increase in alum feed, which may exhaust whatever bicarbonate alkalinity is available.

When there is a deficiency of natural bicarbonate alkalinity, it is commonly compensated for by the addition of soda ash ($NaCO_3$), hydrated lime (CaOH) or caustic soda (NaOH). None of these additives is entirely satisfactory, principally because none actually adds bicarbonate alkalinity but accomplishes the result in an indirect way. Soda ash and caustic soda both are expensive. Hydrated lime has the disadvantage that it raises the pH of the water excessively, which spoils the floc.

Calcium Carbonate

For some time, there has been widespread interest in the use of pulverized limestone, or calcium carbonate ($CaCO_3$), in water treatment plants. This is an intriguing product which has a number of important characteristics. In the first place, it is very inexpensive, selling for about $6 per ton delivered in the East. It is ground to a −325 mesh. With such fineness, it has been used as a coagulant aid to offer a nucleus for floc formation and to give weight to the newly formed floc. The greatest—and almost insurmountable—obstacle to the use of pulverized limestone is its complete insolubility. If it could be dissolved to a concentration of even a few parts per million, it could be very useful; but its solubility is far less than this. Some efforts have, however, been made to utilize this pulverized limestone by reacting it with various agents (*6*).

Experiments

Over a period of several years, extensive research has been done at the author's plant in an effort to discover some practical method of utilizing pulverized limestone in the treatment process. The various known methods were tried with only moderate success. Usually, the end result, when successful, was about the same as that with the standard procedures, but cost considerably more money and effort.

In this research, the objective was to produce true bicarbonate alkalinity ($Ca[HCO_3]_2$). Consequently, it was necessary to obtain a combination of calcium carbonate and carbon dioxide.

In the first experiments carbon dioxide gas was added to the raw water supply of the entire plant under normal conditions. As carbon dioxide is highly soluble, no problems were posed, and any quantity desired could be added. The amount of carbon dioxide that was practical to add to the raw water supply (10–30 ppm) caused no appreciable lowering of the pH. Pulverized limestone was then fed into the raw water. The results were entirely negative; no reaction could be obtained between the pulverized limestone and the raw water even though the carbon dioxide concentration had been raised considerably.

Further experiments were made in the laboratory to determine whether the pulverized limestone could first be dissolved in some suitable acid and then fed into the system. The results of these experiments were encouraging, and it was soon found that the limestone would react if the pH was sufficiently low. Carbonic acid still seemed to be the proper acid to use if it could only be obtained at a sufficiently high concentration and at a low pH.

Pilot Unit

A casual visit to a drugstore soda fountain led to a solution to the problem. A sampling of the carbonated water used to mix soft drinks showed a pH around 4.5. This carbonic acid would react vigorously with the pulverized limestone.

As a result of this discovery, a pilot plant installation was constructed as shown in Fig. 1 and 2. The essential parts of the equipment are a source of carbon dioxide, a carbonator, and a mixing and settling cone.

The carbon dioxide was taken from a bank of 20 cylinders manifolded into a pressure-reducing valve. It was found that liquid carbon dioxide could be purchased in tank truck lots at a cost comparable to that of generating it with oil or gas burners.

Carbonator

A carbonator such as is used in a bottling works was used. This standard form of carbonator consists of a closed pressure vessel which is flooded with carbon dioxide gas at a pressure of 100 psi. Tap water is sprayed into the carbonator by a high-pressure water pump. Agitating paddles within the carbonator are used to obtain an intimate mixture of the gas and water at the 100-psi pressure. This carbonator produced a carbonic acid with a pH of 4.4 and carbon dioxide concentration of about 1,700 ppm.

There is a regulating valve on the discharge of the carbonator which reduces the pressure from 100 psi to about 5 psi, which is the pressure in the mixing cone. Although this reduction in pressure results in some effervescing of the carbon dioxide, it appears that once the carbonic acid is intimately mixed, there is not much loss of gas or increase in pH.

Mining and Settling Cone

A special mixing and settling cone was constructed as shown in Fig. 1 and 2.

The mixing system consists of two concentric cylinders with a stirrer, which creates a violent agitation in this zone. The pulverized limestone is fed into this mixing zone to produce a thick slurry, which is rapidly agitated. The stirring propellers move the slurry upward within the inner cylinder. It flows over the top of the inner cylinder and down between the two cylinders, then upward through the inner cylinder again. Rapid circulation within these cylinders creates a zone of intimate mixing in which the carbonic acid and the particles of limestone are brought together for a considerable length of time.

The carbonic acid enters the mixing chamber from the bottom and is thoroughly mixed with the limestone slurry. It is within this zone that a reaction takes place and produces calcium bicarbonate ($Ca[HCO_3]_2$).

It is most interesting to note that the reaction between the carbonic acid and the limestone only takes place at a pH of less than 6.5, even though there may be excess carbon dioxide.

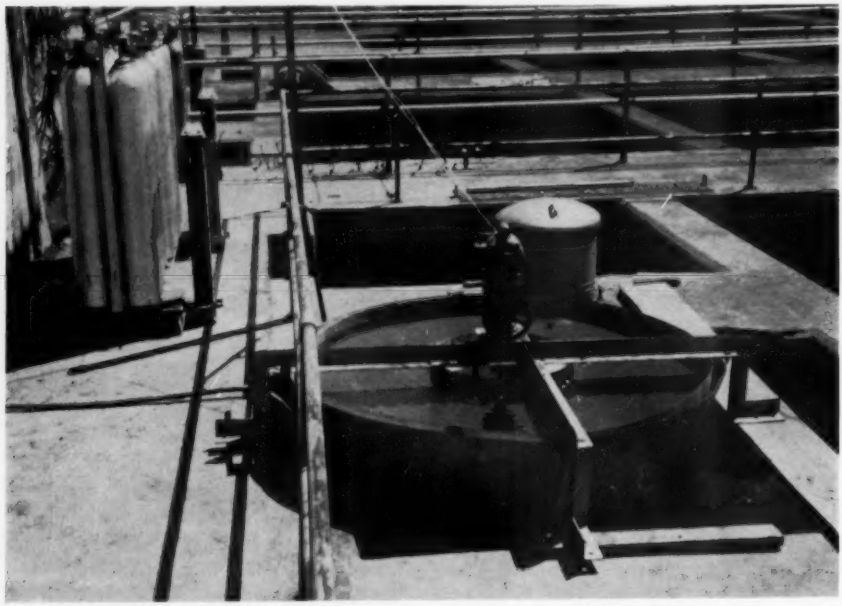

Fig. 1. Pilot Unit for the Production of Bicarbonate Alkalinity

The central cylindrical section with the stirrer is the mixing zone in which the strong carbonic acid is thoroughly mixed with a slurry of pulverized limestone. The outer portion of the cone is the settling zone. Clear effluent flows through an opening into the outer trough and into the plant system.

The excess water, containing the calcium bicarbonate, passes into the settling zone where the limestone slurry settles out and leaves a clear effluent. The settled solution passes over a weir and is discharged into the plant system.

limestone to produce calcium bicarbonate. The remaining 15 per cent did not react and had to be neutralized before being placed in the plant water.

The 250 ppm of carbon dioxide remaining in the effluent from the mixing cone was neutralized with calcium

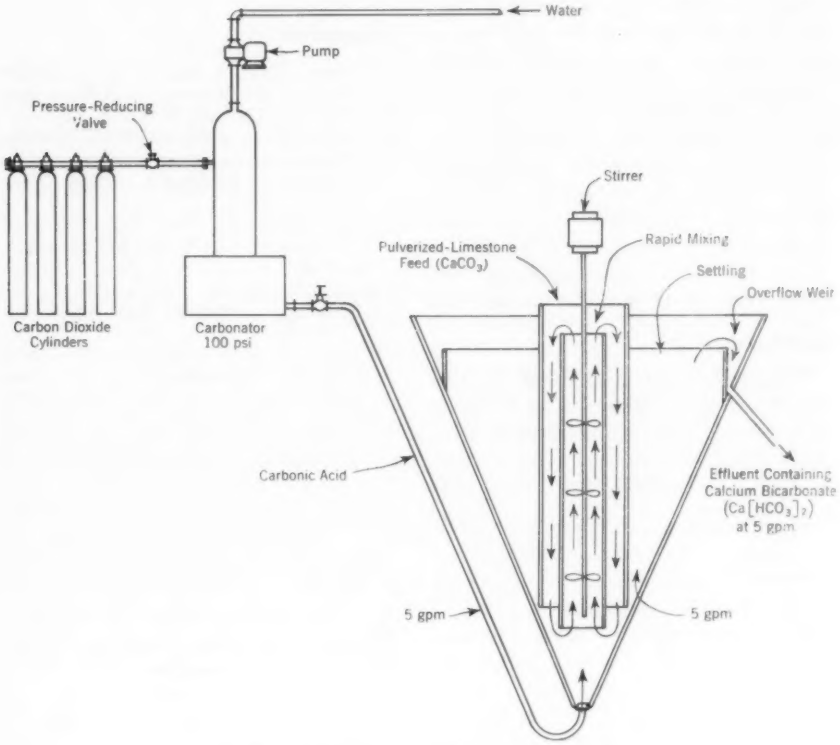

Fig. 2. Schematic Diagram of Pilot Unit

The diagram above is a schematic of the unit shown in Fig. 1.

Results

The effluent from the mixing cone had the following analysis: pH, 6.3; alkalinity, 490 ppm; carbon dioxide, 250 ppm; and calcium, 376 ppm.

In this experiment, 85 per cent of the carbon dioxide reacted with the hydroxide (CaOH). This reaction, in turn, produced more calcium bicarbonate.

A most important determination was made in the feeding of calcium hydroxide to neutralize the carbon dioxide. If the amount of calcium hydroxide is

adjusted carefully so that the carbon dioxide is not entirely reacted but a small amount of free carbon dioxide is allowed to remain in solution, then the maximum amount of calcium bicarbonate is produced and remains in solution. If, through inadvertence, an excess amount of calcium hydroxide is added, it reacts with the acid radical (HCO_3) of the calcium bicarbonate and produces the insoluble calcium carbonate ($CaCO_3$). The latter precipitates out at once, removing any calcium bicarbonate which has been produced and nullifying the entire process. This problem, however, always arises when hydrated lime is used. Whenever an excess is used, it destroys the bicarbonate alkalinity and upsets the alum flocculation process.

Conclusion

The installation described in this discussion was a pilot model designed to determine whether bicarbonate alkalinity could be produced from pulverized limestone and carbon dioxide gas by this process. The results indicate that the process is workable and that good results can be obtained at a reasonable cost. The process should find application at any plant where there is a deficiency of bicarbonate alkalinity in the raw water.

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Determination of Chloride by Precision Null-Point Potentiometry

——*Howard V. Malmstadt and James D. Winefordner*——

A contribution to the Journal by Howard V. Malmstadt, Assoc. Prof., and James D. Winefordner, Research Assoc., both of the Dept. of Chemistry & Chem. Eng., Univ. of Illinois, Urbana, Ill.

VARIOUS titration methods utilizing visual, potentiometric, conductometric, and amperometric end-point detection have been used for determining chloride in water samples (*1*). These methods often are sufficiently accurate if the chloride concentration in the titrated sample is greater than 10 mg/l. If the concentration is less than 10 mg/l, as it is in many water samples, the titration methods give poor results (errors often exceeding 10 per cent). It has been possible to determine chloride concentrations of less than 10 mg/l by several spectrophotometric procedures (*2–6*), but they generally are lacking in precision, accuracy, adequate sensitivity, simplicity, or selectivity. Therefore, a procedure was developed using the new, extremely sensitive, precision null-point potentiometric technique for the chloride determination (*7*), and an automatic pipet for measuring and suitably diluting the water sample.

Briefly, the procedure consists of rapidly changing the chloride concentration of a water sample until it is the same as the chloride concentration of a known reference solution. Obviously, it is necessary to have a measuring system for indicating small differences in chloride concentration between the two solutions; this is done by the precision null-point potentiometric technique (*7*). With this procedure a small aliquot of water sample can be prepared for analysis, the chloride concentration measured by the precision null-point technique, and the final result calculated and recorded, all in about 1 min, with good precision and accuracy. Several ground and river water samples containing 0.03–30 mg/l chloride have been analyzed this way. It is possible also to analyze samples of lower and much higher chloride concentration.

Apparatus and Method

The apparatus and method for measuring chloride in water samples are illustrated in Fig. 1 and 2. The chloride reference solution is put in a $\frac{3}{8}$-in. diameter glass isolation tube, *I*, immersed in a beaker, *B*, containing the diluted water sample. The bottom of the isolation tube has a micro opening (*7*) in contact with the sample solution. Electrical contact can thus be made between the two solutions without significant mixing. For the necessary micro opening, an asbestos fiber sealed in the end of the tube, or small cracks provided by sealing soft glass to pyrex, can be used. A silver-silver chloride electrode, *E*, is immersed in each solution, and the potential across the electrode pair is observed with a

suitable null-indicator. The junction potential is made negligible by preparing the reference and sample solutions and the added reagents to be 1*M* in sulfuric acid. The ions in the water sample contribute negligibly to the ionic strength of the prepared sample, which is essentially equal to the ionic strength of the reference solution in the isolation tube.

The precision null-point potentiometric technique for determining chlo-

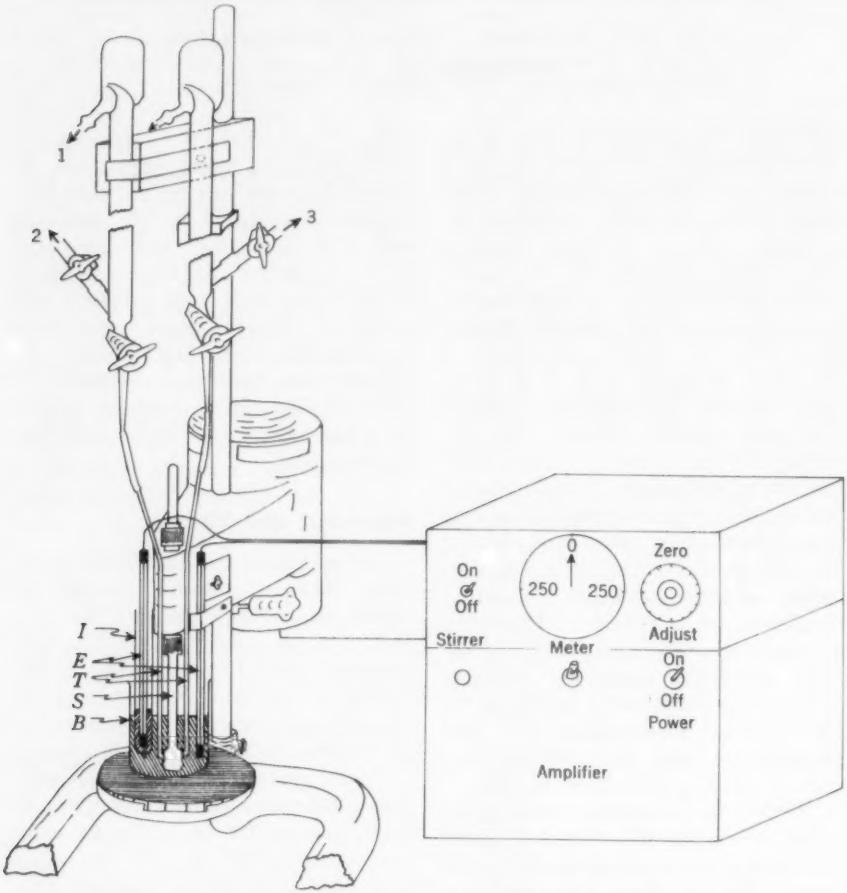

Fig. 1. Experimental Setup for Precision Null-Point Potentiometry

On the left is the stirrer and electrode holder setup; on the right, the null-point detector. The letters in the lower left portion of the diagram indicate the following: I, *isolation tube;* E, *electrodes;* T, *buret tips;* S, *stirrer;* B, *beaker. The numbers near the sidearms indicate connections to: [1] waste receiver, [2] large reservoir containing the standard dilution reagent, [3] large reservoir containing the standard addition reagent.*

ride in water samples consists of rapidly preparing the sample for measurement by simple experimental procedures described herein; pipetting an aliquot of this prepared sample into the beaker, *B*; starting the stirrer, *S*; and adding the appropriate standard reagent from the buret tip, *T*, in order to change the chloride concentration of the prepared sample to the concentration of the known reference solution. If the prepared sample solution is more concentrated in chloride than the reference solution, then the standard dilution reagent is added until the null-point is reached. If the prepared sample is more dilute in chloride than the reference solution, the standard addition reagent is added. The volume of water sample used for analysis and the reference concentration are chosen so that the final result for chloride is obtained by the simple addition or subtraction of two numbers. The decimal place is determined by the volume of sample used for the chloride measurement.

In order to insure efficient stirring and provide a means of holding the beaker, electrodes, and isolation tube, and to allow a simple and rapid change of beakers, a stirrer setup as for electrometric titrations was used.* To obtain the most efficient stirring of the reagent added from the buret and the solution in the beaker, the buret tips, *T*, are pointed at and are nearly in contact with the enlarged end of the stirrer, *S*. The isolation compartment, *I*, and the electrode, *E*, in the beaker, *B*, are held in place by means of clips on the side of the stirrer stand.

The potential between the Ag-AgCl electrode pair is measured by a convenient null-detector, consisting of a high input impedance, d-c chopper amplifier † with a zero-counter, 500-μa meter in series with 1,000-ohm resistor across the output terminals (*8*), as illustrated in Fig. 2. Various amplifiers with similar characteristics are available. Potential changes of 0.02 mv were readily detectable by this system, and no significant polarization of electrodes was observed.

In order to use zero as the null-potential, it is necessary to buck out any small potential between the electrodes when the solution in the beaker is the same concentration as that in the reference compartment. This is done by using a zero-adjust circuit that will supply a maximum of 1 mv of bucking voltage. If there is more than 1 mv across the electrodes, so that balance cannot be achieved, then something is wrong with the electrodes or the isolation compartment, and the system should be checked.

Automatic, self-zeroing, 25-ml, precision-bore Teflon‡ stopcock burets § are used for adding the standard reagents. Each buret is filled through a sidearm fitted with a Teflon stopcock connected to a large reservoir containing the appropriate reagent. A short piece of polyethylene tubing is used to connect the tip of each buret to the delivery tips.

Automatic flushout pipets with three-way stopcocks are convenient and accurate for pipetting 1.000, 0.1000, and 0.01000 ml of water samples. The pipets can be prepared and calibrated as described by Seligson

* The setup used was that for the Sargent-Malmstadt Electrotitrator, manufactured by E. H. Sargent & Co., Chicago, Ill.

† Model M-10; a product of Mandrel Industries, Houston, Tex.

‡ A product of E. I. du Pont de Nemours & Co., Wilmington, Del.

§ Manufactured by Fischer & Porter Co., Hatboro, Pa.

(*9*). Volumetric pipets can, of course, be used instead of the automatic flush-out pipets, but they are usually not as convenient and accurate for analyzing small volumes of samples.

An automatic, 10-ml pipet with a three-way Teflon stopcock for delivery and filling is used to deliver accurately 10.00 ml of 2*M* H_2SO_4. The sidearm of the pipet is connected to a large reservoir of 2*M* H_2SO_4.

the titrant and select a suitable buret, so that the buret-reading errors are within the error limit. It is desirable, however, to have some idea of the concentration of the sought-for constituent in order properly to choose conditions for accurate measurements.

In the precision null-point potentiometric technique for chloride, some considerations are quite analogous to those inherent in the titration method.

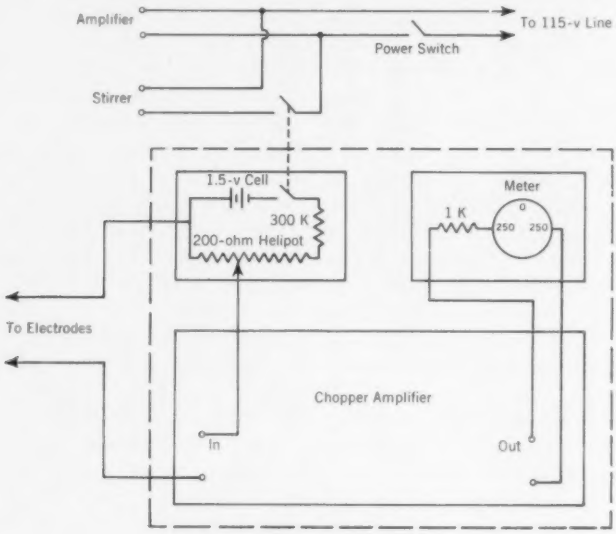

Fig. 2. Null-Point Detector

The schematic diagram shows the measurement and control system.

Reagent Solutions

The determination of a sought-for constituent that varies greatly in concentration from sample to sample presents problems for most methods of analysis, especially if high accuracy is desired throughout the concentration range. If a titration procedure is used and a sensitive endpoint detection method is available, it is, of course, possible to change the concentration of

For one, it is desirable to choose suitable concentrations of sample and other reagents so that buret-reading errors will not cause other significant errors. Therefore, the concentration of reagents for the given procedure was chosen to provide good results over a wide chloride concentration range of about 0.04–4,000 mg/l. The methods of preparation and concentrations of reagents used in preparing water sam-

ples for analysis by precision null-point potentiometry are described below. Other concentrations of reagents could be used to cover other ranges or to decrease relative errors over a limited range.

Stock sulfuric acid solution. A large volume (about 25 liters) of 5*M* H_2SO_4 was prepared by diluting reagent grade, concentrated H_2SO_4 with deionized water (using 300 ml concentrated H_2SO_4 per liter of stock solution prepared).

2M sulfuric acid solution. A large volume of 2*M* H_2SO_4 solution was prepared by pipetting an appropriate aliquot of the 5*M* H_2SO_4 stock solution in a volumetric flask and diluting to the mark with deionized water.

Stock sodium chloride solution. One liter of 100.0 mg/l Cl^- was prepared by weighing out reagent grade sodium chloride and diluting to volume with deionized water. Several liters of 10.00-mg/l Cl^- solution were prepared by diluting the 100.0 mg/l Cl^- with deionized water.

1.000-mg/l Cl^- reference solution. For each liter of reference solution that was prepared, 100.0 ml of 10.00 mg/l Cl^- and 200.0 ml of 5*M* H_2SO_4 stock solution were added to the volumetric flask and diluted to volume with deionized water.

Standard dilution reagent. For each liter of dilution reagent that was prepared, 200.0 ml of 5*M* H_2SO_4 stock solution was added to the volumetric flask, and diluted to volume with deionized water. (If many chloride analyses are to be performed, it is convenient to make ten or more liters at one time.)

Standard addition reagent. For each liter of reagent that was prepared, 200.0 ml of 10.00 mg/l Cl^- and 200.0 ml of 5*M* H_2SO_4 stock solution were added to the volumetric flask, and diluted to volume with deionized water.

Preparation of Samples

Water samples are prepared for measurement as follows, depending on the chloride concentration range of the samples.

0.04–4 mg/l chloride. Pipet 10.00 ml of the water sample into a clean, dry, 50-ml beaker and add 10.00 ml of 2*M* H_2SO_4 reagent. A 10-ml volumetric pipet is convenient to use for the water sample, and a 10-ml automatic pipet for addition of the 2*M* H_2SO_4.

2–40 mg/l chloride. Place several milliliters of water sample into position under the tip of the 1.000-ml automatic pipet, and after flushing with a few milliliters retain the water sample in the pipet tip. Rinse this 1.000-ml aliquot sample into a clean, dry, 50-ml beaker with 9.00 ml of deionized water from the buret attached to the pipet (note that 10.00 ml of deionized water is added from the buret, but 1.00 ml is retained in the pipet). At the same time that the water sample is added, a 10.00-ml portion of 2*M* H_2SO_4 is placed in the 50-ml beaker from the automatic, 10-ml pipet. At this point, the 1.00-ml water sample has been diluted to 20.00 ml, which is 1*M* in H_2SO_4. Prior to positioning the next water sample under the pipet tip, the deionized water in the pipet tip is drawn out by suction, and the rinsing buret is refilled from a reservoir containing deionized water. Also, the self-zeroing, automatic, 10-ml pipet is refilled from a reservoir containing 2*M* H_2SO_4.

It is, of course, possible to use ordinary pipets to deliver the 1.000-ml water sample, the 9.00 ml of deionized water, and the 10.00 ml of 2*M* H_2SO_4

into the 50-ml beaker, but they are not as convenient as the automatic pipets for routine analysis of large numbers of samples.

20–400 mg/l chloride. Use the same procedure as described above for the 2–40-mg/l chloride range, except that 0.1000 ml of water sample and 9.90 ml of deionized water are to be used.

200–4,000 mg/l chloride. Use the same procedure as described for the 2–40-mg/l chloride range, but use 0.01000 ml of water sample and 9.99 ml of deionized water. The rapid and accurate delivery of these two volumes is most easily accomplished with the automatic pipet–buret combination (*9*), although a syringe micropipet can be used for the 0.01-ml water sample and a 10-ml volumetric pipet for the deionized water.

Determination of Concentration Range

If the chloride concentration range of certain samples is not known, it is necessary to determine the approximate concentration in order to dilute the sample properly to obtain accurate chloride results. This is readily accomplished by diluting a 0.1-ml water sample to 20 ml, as was done for the chloride concentration range of 20–400 mg/l. Addition or dilution reagent is then added, depending on the direction of deflection of the null-indicator. If 0–18 ml of addition reagent or 0–20 ml of dilution reagent are sufficient to reach the null-point, then the volume added, V_a, and the sample volume, V_s, equal to 0.1000 ml, can be used for the accurate determination of the chloride concentration. If 18–19.7 ml of addition reagent are necessary to reach the null-point, a 1-ml aliquot of the water sample is treated, as for the concentration range of 2–40 mg/l chloride. If 19.7–20 ml of addition reagent are necessary, a 10-ml aliquot of water sample is treated, as for the concentration range of 0.4–4 mg/l chloride.

If the null-detector indicates that dilution reagent should be added, and the null-point is not reached after adding about 20 ml (approximately the maximum volume that can be added without overflowing the 50-ml beaker containing electrodes, stirrer, and other apparatus), then a 0.01-ml water sample should be used according to the sample preparation procedure for the 200–4,000-mg/l range.

Establishment of Null-Point

At the beginning of each day, the asbestos fiber isolation compartment is emptied and filled to at least a few milliliters above the top of the Ag-AgCl plate electrode with fresh 1.000-mg/l Cl^- reference solution. The isolation compartment is positioned in the beaker as shown in Fig. 1, the reference solution placed in both the beaker and the isolation compartment, the stirrer started, and the potential between the two electrodes observed on the null-detector. In order to have a null-point at zero, any small potential between the two electrodes is bucked out by means of the zero-adjust control. After every five or ten determinations, the null-point should be rechecked, using the reference solution in the beaker. The null-point does not vary by more than ± 0.05 mv, unless unusually large amounts of bromide are present in the samples.

Measurement of Concentration

After setting the null-point, the reference solution in the beaker is re-

moved. A beaker containing the 20 ml of prepared sample is placed into position and the stirrer started. Depending on the direction of deflection of the null-indicator, either the addition or dilution reagent is added from the appropriate buret with the stopcock wide open until the null-point is nearly reached, at which time delivery of reagent is stopped. Small increments of reagent are then added by rapid rotation of the stopcock until the null-point is reached, the buret reading is recorded to obtain volume V_a, and the chloride concentration is calculated using the expression below. Between determinations, the buret used is refilled with suitable reagent.

Calculations

The concentration of chloride in water is often expressed as "mg/l," which is, of course, equal to μg/ml, and is calculated from the following expression:

$$\frac{C_R}{V_s}(V_o \pm V_a)$$

in which V_s is the volume (ml) of the water sample actually used for the chloride measurement by precision null-point potentiometry, C_R is the chloride concentration (mg/ml) of the reference solution, V_o is the volume (ml) of the prepared solution taken for measurement (20.00 ml in the given procedure), and V_a is the volume (ml) of standard dilution or addition reagent used in reaching the null-point (either 1*M* H_2SO_4 or 2.000 mg/l Cl^- in 1*M* H_2SO_4). If addition reagent is added, V_a is subtracted from V_o; if dilution reagent is added, V_a is added to V_o.

Because C_R is 1.000 mg/l Cl^-, and V_s is 10, 1, 0.1, or 0.01 ml, the chloride concentration is equal to $V_o \pm V_a$, multiplied by 0.1, 1, 10, or 100 for the concentration ranges 0.04–4, 2–40, 20–400, and 200–4,000 mg/l chloride, respectively. For example, a water sample containing 4.00 mg/l Cl^- could be prepared for analysis either by pipetting a 10.00-ml aliquot of the water sample into a 50-ml beaker and adding 10.00 ml of standard 2*M* H_2SO_4, or by pipetting a 1.000-ml aliquot into a 50-ml beaker and adding 9.00 ml of deionized water and 10.00 ml of standard 2*M* H_2SO_4. In either instance, the total volume of the prepared sample, V_o, is 20.00 ml. In the former, the null-detector would indicate that dilution reagent should be added, requiring a volume V_a of 20.00 ml to reach the null-point. In the latter, it would be necessary to deliver addition reagent, requiring 16.00 ml to reach the null-point. Therefore, the chloride concentration of the original water sample would be 0.1 (20.00 +20.00) in the former and 1(20.00–16.00) in the latter, giving a final result of 4.00 mg/l Cl^- by either method. This example also illustrates that the buret-reading error is less significant in the first instance than in the second, and that the relative error increases as the difference between V_o and V_a decreases.

Results and Discussion

In order to check the reproducibility and accuracy of the sample preparation procedure and measuring system, two sodium chloride solutions containing 20.00 and 3,546 mg/l Cl^- were each determined several times by the given procedures for the 2–40-mg/l and 200–4,000-mg/l ranges, respectively. The results in Table 1 illustrate the precision and accuracy of the entire procedure when buret-reading errors are at a minimum.

TABLE 1

Chloride Determination in Known Samples by Precision Null-Point Potentiometry

Concentration Found *mg/l*	Deviation *mg/l*
20.00-mg/l Cl^- Solution	
20.00	0.00
20.03	0.03
19.96	0.04
19.98	0.02
20.00	0.00
20.04	0.04
Avg 20.00	Avg 0.03
3,546-mg/l Cl^- Solution	
3,553	4
3,543	6
3,546	3
3,556	7
3,550	1
3,544	5
Avg 3,549	Avg 4

TABLE 2

*Chloride Determination in Ground and River Water Samples by Precision Null-Point Potentiometry**

Sample No.	No. of Determinations	Found *mg/l*	Avg Deviation *mg/l*
1	5	29.9	0.1
2	5	27.2	0.1
3	5	12.1	0.2
4	5	16.8	0.1
5	5	10.2	0.1
6	5	8.44	0.03
7	3	7.76	0.04
8	4	6.45	0.04
9	4	5.38	0.05
10	4	3.97	0.03
11	3	1.57	0.02
12	3	1.52	0.02
13	3	0.03	0.01

* A 1,000-mg/l Cl^- reference solution was used for all samples, which were obtained from the Illinois State Water Survey.

The chloride concentration in several ground and river water samples, which were prepared for analysis as previously described, was determined using the given sample preparation methods and the precision null-point potentiometric chloride measurement. The results are given in Table 2. Samples 1–10 were determined using the sample preparation method for chloride concentration in the 2–40-mg/l range. Samples 11–13 were determined by diluting a 10-ml water sample, as was done for samples in the 0.04–4-mg/l range.

The chloride concentration in Samples 1–12 was checked by the standard Mohr method, and in all cases the average titration result was within 1 mg/l of the result by the new method. The precision was at least ten times better by the new precision null-point method than by the titration method.

The larger relative error for Sample 13 is a result of the buret-reading error, which could be reduced considerably by using a more accurate buret or by changing the procedure and using a more dilute chloride reference solution, possibly 0.1 mg/l Cl^-. Precision and accuracy within about 0.01 mg/l, however, are often sufficient at these low chloride concentration levels.

It should be noted that the actual concentration of the stock sulfuric acid solution is not too important, but it is important that the sulfuric acid concentration be the same for samples and standard reagents, so that the liquid junction potential is negligible (*7*). Also important is that the sulfuric acid used for samples and reagents come from the same H_2SO_4 reagent bottle, so that the chloride contribution from the sulfuric acid cancels out and does not enter into the calculation for chloride in the samples. For these rea-

sons, it is recommended that a large volume of 5*M* stock sulfuric acid be prepared.

The interferences with the precision null-point potentiometric technique for chloride are quite similar to those for the argentimetric titration procedure, including any cations and anions that might precipitate or complex with chloride or silver ions. These ions include I^-, Br^-, CN^-, S^-, and Fe^{+++}, which are often in water samples. They are not, however, usually present in ground and river water samples in sufficient quantities to cause any significant interference.

Synthetic samples containing quantities of Ca^{++}, Fe^{+++}, Na^+, I^-, Br^-, Po_4^{---}, and CN^- in the presence of known quantities of chloride, typical of water samples, gave chloride results that checked closely with the known values.

Bromide shows anomalous behavior as previously described (*7*), and it is desirable that its concentration not exceed 0.01 mg/l in the diluted sample. If the bromide concentration exceeds 0.05 mg/l, there will be significant drifting of the electrode potential, and it will be difficult to determine the null-point accurately.

Summary

A new, rapid, accurate procedure is described for the determination of chloride in ground and river water samples. The samples are rapidly prepared for analysis, and the chloride is measured by precision null-point potentiometry. Small water samples of 0.01–10 ml are used to cover the wide chloride concentration range of about 4,000–0.04 mg/l; the concentration of standard reagents remains the same throughout this range. The entire procedure for chloride determination in typical water samples, including sample preparation, chloride measurement, and calculation of final results, requires only about 1 min.

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Standards of Purity for Liquid Chlorine

Edmund J. Laubusch

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A STANDARD for liquid chlorine, AWWA B301, first published as tentative in 1958 (*1*) was approved as standard in January 1959. Except for the federal specification (*2*) this is the only model quality standard for chlorine in the United States. Although more than 120,000 tons of chlorine are purchased annually for sanitary uses (*3*), which account for 2–3 per cent of the total chlorine production, it is the last major water treatment chemical to have been included in AWWA's 68-year-old standards program. These facts are especially significant because the increasing sanitary uses of chlorine over the past 50 years have made chlorine the most widely used water treatment chemical.

The purposes of this article are twofold: [1] to outline various gaps in present knowledge concerning chlorine impurities and the effects of impurities on process applications and [2] to indicate the steps being taken to eliminate or minimize the difficulties and hazards associated with chlorine uses.

The existence of no industry-wide standard for chlorine purity is evidence of the responsibility assumed by chlorine producers and their ability to supply consistently a high-quality product for commercial use. In view of the extensive use of chlorine for water treatment, operating problems which may be caused by chlorine impurities apparently have not been of sufficient magnitude to necessitate more exacting quality control. In rare instances, lots of "impure" chlorine have reached sanitary and other users, but these have probably been no more frequent than could be expected even if purchases were made in accordance with a particular quality standard. It may be useful, however, to review the reasons why a standard was not provided earlier.

In considering the nature and effects of impurities in liquid chlorine, it is necessary to review briefly the methods used in the manufacture and distribution of commercial liquid chlorine, some of the characteristics of the material, and the sources of impurities that affect its use for sanitary purposes.

Production

Chlorine is not found free in nature; it exists abundantly in the form of chlorides, the most important and common of which is ordinary table salt, sodium chloride. Commercial chlorine is produced almost entirely by electrolysis of this salt:

$$2NaCl + 2H_2O \xrightarrow[\text{Current}]{\text{Direct}} Cl_2 + H_2 + 2NaOH.$$

A small amount of chlorine is obtained incident to the production of sodium

by electrolysis of molten sodium chloride; it can also be prepared chemically (by nonelectrolytic means), but such processes are not in general commercial use.

The electrolytic reaction is carried out in cells of various designs, which contain and separate the raw material and decomposition products. Two fundamental types of cells are employed, diaphragm and mercury, but the quality differences in chlorine from these are not of any apparent moment insofar as sanitary uses are concerned.

The diaphragm cell (Fig. 1) consists of two compartments separated by a porous asbestos diaphragm. Graphite anodes are located in one compartment, in which chlorine gas is formed. A perforated steel plate, the cathode, is located in the other compartment, in which hydrogen gas and sodium hydroxide are formed. The diaphragm prevents reaction of the cell products and serves as a membrane permeable to the passage of brine and d-c electricity. In the typical mercury cell, chlorine gas is also liberated at the anode. Sodium is dissolved in the mercury cathode, forming amalgam which flows into a denuding compartment where the sodium reacts with water to form sodium hydroxide.

In both types of cells, chlorine is withdrawn as a hot gas saturated with moisture. Removal of this moisture is important; it is accomplished by cooling the gas and scrubbing with concentrated sulfuric acid, after which ordinary construction materials that are unaffected by dry chlorine are used in handling the product. That portion of the cell gas intended for commercial use is liquefied by compression and cooling to a low temperature, which separate the liquid chlorine from noncondensable gases. The liquid chlorine is then packaged in suitable containers for sale.

Sources of Impurities

Purity of chemical commodities, including chlorine, is an abstract consideration. Chlorine producers do not aim to provide a product absolutely free of impurities; this is impractical on a commercial scale. Their aim is to supply a product which is reasonably free from those impurities whose presence in appreciable quantities is known to be unsafe or objectionable in transportation and use.

Chlorine Characteristics

Dry chlorine, either as a gas or liquid, is not corrosive under normal temperature conditions. In the presence of even small amounts of moisture, however, it reacts to form a mixture of hypochlorous and hydrochloric acids which is extremely corrosive. These acids not only may cause equipment failure, but they also enhance the solution of iron and other materials that react with chlorine to form insoluble metallic salts. Such salts can easily clog small pipes, orifices, and other susceptible parts of chlorine-feeding equipment. These are dangers that producers, repackagers, and consumers must continually guard against, and problems that require constant vigilance.

Under suitable conditions, chlorine reacts with nearly all of the chemical elements and with many compounds. For example, it reacts with steel at temperatures above about 450–500°F. Similarly, it can react with ammonia to form nitrogen trichloride. Nitrogen trichloride, a very stable compound, is

soluble in liquid but not in gaseous chlorine, but it may be explosive under certain conditions. Trace amounts of ammonia may be present in certain brines and may be removed by superchlorination.

In the presence of organic hydrocarbons, chlorine combines with hydrogen to form other hydrocarbons and hydrogen chloride. Much heat is often evolved from these reactions. The reactions for the formation of methylene chloride, chloroform, and carbon tetrachloride are given below (in that order).

$$CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$$

$$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$$

The list of potential chlorine impurities, then, includes a number of chlorinated hydrocarbons, inorganic chlorides, and dissolved gases, depending upon the raw materials, cell components, and processes employed. The list also includes impurities resulting from contact between chlorine and various materials of construction, air and moisture in processing, shipping, repackaging, and consuming equipment. It is important to use pipelines, packing and jointing materials, and other equipment and appurtenances that minimize contact of chlorine with chlorine-vulnerable substances.

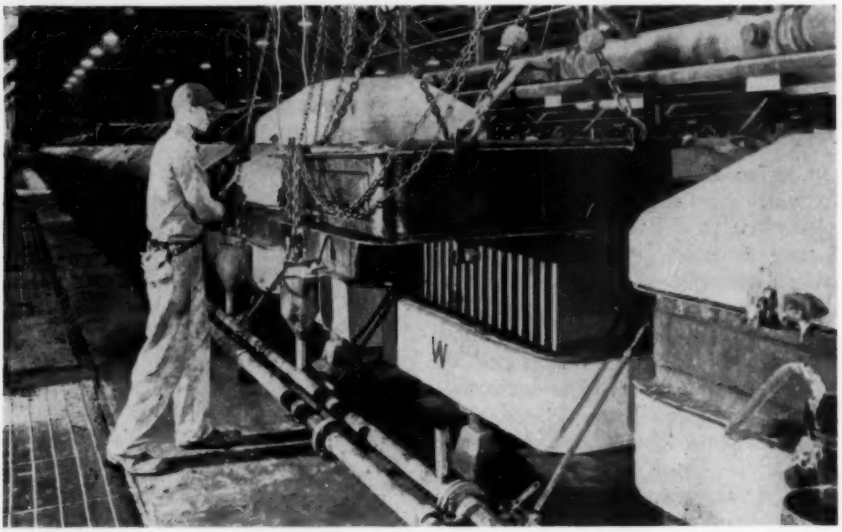

Fig. 1. Chlorine Cell Room

A diaphragm cell is here being serviced. Chlorine gas is produced electrolytically from purified salt brine. In the United States, 80,000 tons of chlorine is used annually for water treatment alone.

Manufacturing

The source of a substantial number of impurities in electrolytically pro-

duced chlorine is the raw material employed—that is, salt, as an aqueous solution, as brine, or in the molten state. The diaphragm cell process uses either dissolved salt or brine, whereas the mercury cell process is often more efficient when salt is used instead of brine. In either case, the quality of the raw material varies considerably and is influenced by the quality of the dissolving water and other factors. Producers carefully control the purity of salt or brine fed to cells. In the diaphragm process, for example, complete removal of calcium and magnesium oxides is essential to prevent blockage of the diaphragm through the precipitation of lime and magnesium in the presence of causticity; removal of heavy metal impurities is desirable for the same reason. Sodium hydroxide or sodium carbonate is employed for this purpose. Precipitates are carefully filtered from the solution before it is fed to the cell. Similar removals also are required in mercury processes; if not removed, the precipitates could result in objectionable or, possibly, dangerous concentrations of hydrogen in the chlorine.

Other impurities (especially ferric chloride, hexachlorethane, carbon tetrachloride, and chloroform) originate during contact between the chlorine and materials used in its preparation, drying, and liquefaction. These materials include packing, lubricants, resinous sealing compounds for cells and joints, and the binder for the graphite anodes used in the diaphragm cell process (*4*).

No efforts are spared to dry the chlorine gas withdrawn from the cells, because even a very small amount of moisture in gaseous or liquid chlorine makes it extremely corrosive to steel and other common metals with which it comes in contact. As already noted, moisture is effectively removed by scrubbing the gas with concentrated sulfuric acid. Occasionally, small amounts of sulfuric acid from this source are carried in the chlorine.

During cooling and liquefaction, noncondensable gases are separated from the liquid chlorine. The dissolved atmospheric gases that remain usually do not affect chlorine quality, and rarely exceed 0.05 per cent by volume. Special efforts are made to limit the concentration of nonvolatile impurities to less than 20–30 ppm because they can clog pipes, valves, and control equipment. The concentration of some other impurities, such as silicon tetrachloride, which is common only to chlorine produced incident to electrolytic sodium production, can be effectively reduced by washing the gas with liquid chlorine; this practice is employed by producers as necessary.

Storage and Distribution

The sales mechanism of the chlorine industry has been changed considerably during the past 20 years by the development of repackagers who purchase chlorine from producers in tank cars or other containers and transfer it to other shipping containers. In 1945 there were twelve known repackaging plants in the United States; today there are at least 55. A substantial portion of the chlorine used for water and waste treatment is distributed in this manner, and proportionately lesser amounts are being sold directly by the producers.

Responsibility for the quality of chlorine used at sanitary facilities cannot be placed wholly on the producer. Shipping and repackaging equipment

may provide opportunities for contact between liquid or gaseous chlorine and chlorine-vulnerable materials before it reaches the consumer. Moreover, the human element in each of the phases, no less than at the point of use, has an important and inescapable bearing on the matter.

Use

A large number of consumer complaints are made regarding the deposition of foreign materials in orifices or delicate moving parts of chlorine gas-dispensing equipment. The materials that cause these difficulties (present in concentrations of negligible diluent significance) are commonly called "taffy." They consist largely of a complex of chlorinated organic compounds and, if moisture has entered the system, some ferric chloride.

TABLE 1

Impurities Found in Chlorine

Gases	Nitrosyl chloride
Carbon dioxide	Nitrogen tetroxide
Hydrogen	Nitrogen trichloride
Oxygen	Silicon tetrachloride
Nitrogen	Sulfuric acid
Volatile Liquids	*Nonvolatile Solids*
Bromine	Ferric chloride
Carbon tetrachloride	Ferric sulfate
Carbonyl chloride	*Volatile Solids*
Hydrochloric acid	Hexachlorobenzene
Methylene chloride	Hexachlorethane

Published references (*4, 5*) suggest that the majority of such difficulties are attributable to maintenance errors or negligence at the feeding facility. For example, atmospheric moisture may enter a system during shutdown; lubricants and cleaning solvents that can react with chlorine may not be properly removed before the system is returned to service; lubricants and packing materials may be forced into the system by excess tension on packing glands; protective diaphragms of pressure gages may become ruptured and discharge diaphragm oil into the system; or deposition of several months' chlorine flow may suddenly be redissolved by condensing droplets of liquid chlorine and deposited at the first point of gas expansion. Clearly, then, there are numerous opportunities for chlorine contamination incident to the feeding process.

Types of Impurities

Technical literature contains little of a specific nature on chlorine quality stipulations. Some of the impurities that have been observed in chlorine are given in Table 1. Obviously, no single supply of chlorine contains all of these impurities, and chlorine producers do not routinely employ assay tests for all. Gaseous impurities that are not separated from chlorine during liquefaction do not cause operating difficulties at chlorination facilities and, owing to their solubility characteristics, never are present in such amounts as to be of diluent significance. Manufacturers give particular attention to those impurities that are known to cause difficulties, however. Moisture can be approximated by evaporating liquid chlorine and then making a gravimetric determination; many other impurities can be approximated by spectrophotometry, chromatography, ultraviolet absorption, and chemical means.

Actually, the percentage purity of commercial chlorine is exceptionally high. The small concentration of impurities may, however, still be a problem peculiar to chlorinator operation in the sanitary field. Thus, the model federal specification (*2*), ". . . 99.5 per

cent pure by volume as obtained from vaporized liquid chlorine . . . ," may actually be too liberal, because chlorine containing as little as 0.2 per cent of certain impurities may cause great trouble in a chlorinator (*3*). Furthermore, that part of the federal and AWWA standards calling for chlorine that is "suitable for the treatment of water, sewage, and industrial wastes" leaves even more to be desired. All chlorine producers market a chlorine of greater than 99.5 per cent purity, and they ordinarily remove or reduce those particular impurities believed likely to create difficulties in transit and in process applications.

The impurities frequently reported to cause operating difficulties to sanitary users include ferric chloride, hexachlorethane, nitrogen trichloride, and silicon tetrachloride. (The sources and effects of moisture have been considered previously.) It is, of course, possible that additional impurities are involved, alone or in combination. Limiting concentrations of these impurities, however, have not been determined by experimental or trial means.

Current Status of Problem

The development and promulgation of a standard for any commodity should logically be based on facts. Although there is uniformity in the description of certain operating problems reportedly caused by "impure" chlorine, the precise composition of the impurities has not been established, despite the many theories that have been advanced. In addition to the problem of moisture, which is not attributable to any production deficiency or irregularity, it is quite generally accepted that impurity problems at sanitary facilities are caused by diluently insignificant concentrations of: [1] inorganic chlorides, and [2] a complexity of chlorinated organic compounds having vapor pressures that permit sublimation at room temperatures. Some organic impurities that may be present, such as chloroform and carbon tetrachloride, may readily be volatilized and removed with chlorine gas. Some organic compounds, however, such as hexachlorobenzene and hexachlorethane, are believed to be recondensed under certain conditions of temperature variation and pressure reduction (cooling) in the chlorination system.

While the AWWA standard for liquid chlorine (B301) was being drafted, it became very evident that nobody could state with certainty which impurities, above what limiting concentrations, and under what conditions, were objectionable. Furthermore, no uniformly acceptable assay techniques for their determination existed, even among chlorine producers. In the absence of such techniques, a really definitive standard was not possible. In submitting the standard to its members, AWWA properly took cognizance of these shortcomings. It was properly noted that pending the development of qualitative and quantitative analytical methods, criteria could not be offered for chlorine "suitable for the treatment of water, sewage and industrial wastes."

In an effort to correct the shortcomings of the standard, AWWA encouraged research on these matters. A USPHS-supported investigation was initiated at Purdue University in June 1958. The research has as its objective a definition of those impurities in liquid chlorine which are of interest to sanitary users, and the development of

suitable analytical methods for their determination. Following the development of these methods, limiting concentrations might be derived by trial and experience. All of this is fundamental to a standard for liquid chlorine.

It remains to be established whether the final solution to the impurities problem will lie in more rigid quality control, improved operation and maintenance procedures, modification of equipment, or a combination of all of these factors.

Acknowledgment

The author is grateful for the helpful reviews and suggestions made by Harry A. Faber of the Division of Sanitary Engineering Services, USPHS.

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Effectiveness of Coarse-Grained Media for Filtration

Loren R. Heiple

A contribution to the Journal by Loren R. Heiple, Prof., Dept. of Civ. Eng., Univ. of Arkansas, Fayetteville, Ark.

EFFECTIVE reduction of turbidity and removal of bacteria by filtration of normal surface waters through coarse-grained filter media have been reported, but, for the most part, the reports have been sketchy and without substance. Exceptions are the reports by Suter (*1, 2*) of ground water recharge experiments at Peoria, Ill., where 4–5-mm pea gravel removed silt and bacteria from Illinois River water without the hydraulic restriction and rapid clogging customary with filter sand.

The effectiveness of filtration with coarse-grained media as filtering agents for colloidal and noncolloidal particles has been investigated for the past 3 years by the civil engineering department of the University of Arkansas. With the completion of the major portion of a programed investigation it has been established that at low filtration rates gravel removes a substantial portion of suspended particles in water drawn from surface sources.

Preliminary Experiments

Field experiments were initiated to determine if further detailed investigation was warranted. In addition to determination of general filtration effectiveness, two specific questions for investigation were the effect of filtration rate on filter efficiency and whether the filter would operate as a trickling filter (medium exposed to air while water percolates through it) and as a submerged filter.

Field Equipment

The filter unit for this study consisted of a steel shell with a cross-sectional area of 1 sq ft. Arrangements were made for backwashing to clean the filter medium, although, during the investigation, the medium was usually removed and replaced between runs. Manometric tubes were fastened to the filter in order to measure head loss during operations. The rate of filtration was controlled by a manually operated valve.

The filter equipment was located on the bank of a farm pond chosen because of its high turbidity resulting from heavy animal usage. During the experiments this water varied in turbidity from 70 to 285 ppm. No treatment was given to the pond water before filtration.

A first series of operations with the filter of coarse-grained medium utilized a 42-in. depth of $\frac{1}{4}$–$\frac{3}{8}$-in. diameter washed river gravel at rates of operation varying from 0.1 to 1.0 gpm/sq ft. Data are presented in Table 1. All the runs were of short duration, obviating any aging effect. The longest run was 9 hr of continuous operation and the

TABLE 1

Turbidity Removal at Varying Rates of Filtration, Submerged Operation

Rate of Operation *gpm/sq ft*	Length of Run *hr*	Turbidity* *ppm*		Reduction *per cent*
		Raw Water	Filtered Water	
1.0	4.0	113	71	37
0.75	4.0	170	101	41
0.75	3.0	197	93	53
0.25	3.5	116	47	59
0.25	5.0	87	37	57
0.10	1.5	100	20	80

* Values averaged throughout individual run.

shortest was 1.5 hr. The head loss at the end of each run was negligible and the turbidity reduction in the filtering process was 37–80 per cent. Turbidity removal increased as the rate of operation was reduced until the optimum removal of 80 per cent was reached at a filtration rate of 0.1 gpm/sq ft.

When the same gravel filter was operated as a trickling filter, it was again noted that the turbidity reduction increased as the rate of operation decreased (Table 2). The amount of reduction, however, was so low that no further consideration was given to trickling filtration through coarse media.

Preliminary field operations were hampered by unforeseen factors that influenced experimental data and dictated that further study should be under controlled conditions obtainable only in the laboratory. The complicating variables encountered in the field operations are described below:

1. The turbidity varied greatly in measured quantities (parts per million on the silica scale) as well as in particle size. Shortly after heavy rains the particles were coarse and settleable, whereas after a lengthy settling period a major portion of the suspended matter was of colloidal size. Normal measures of filter efficiency (based on light transmittance) were undoubtedly affected by the amount of material, measured on a weight basis, as well as by the type of turbidity according to particle size.

2. Other factors influencing field observations included temperature, amount of turbidity, the composition of suspended particles (whether organic or inorganic).

It was concluded that results were promising enough to justify continued investigation of coarse-grained filter media under submerged operation. In the light of preliminary data, further study was limited to filtration rates in the 0.1–0.25-gpm/sq ft range.

Laboratory Investigations

Laboratory investigations were designed to determine: [1] the effect of the depth of the filter medium on

TABLE 2

Turbidity Removal at Varying Rates of Filtration During Operation as a Trickling Filter

Rate of Operation *gpm/sq ft*	Length of Run *hr*	Turbidity* *ppm*		Reduction *per cent*
		Raw Water	Filtered Water	
1.0	4.0	104	94	10
0.75	2.5	94	89	5
0.75	5.0	78	73	6
0.25	4.0	85	67	21
0.25	4.0	87	66	24
0.10	2.0	85	75	12
0.10	7.0	82	61	25

* Values averaged through each individual run.

the efficiency of filter in removing turbidity; [2] the effect of the medium size and the nature of filter medium on efficiency; [3] the relation of filter efficiency to the depth of water above the surface of the filter bed; and [4] the effect of medium particle size on the operation of the filter.

The basic equipment in laboratory investigation was the steel cylinder filter previously described, augmented by 4-in. lucite cylinders to make possible visual observation of filtration action. Two types of raw water were employed. An artificially turbid water was used for investigations in which it was desirable to limit the variance in the water turbidity to a minimum. In those investigations in which it was necessary to determine the relative effectiveness of the filter in filtering particles of colloidal size, settled pond water was employed This pond water was collected in a reservoir for a 24-hr period and allowed to settle. At the end of this time the water was decanted and transported to the laboratory. The artificially prepared turbidity was designed for a mean value of 85 ppm, with a variance ranging from 50 to 100 ppm, but remaining relatively constant for any one phase of the investigation. The first series of experiments was completed using artificially turbid water prepared from clay obtained from a local deposit. This clay was washed through a No. 200 sieve and the resulting slurry was dried, pulverized, and resieved. Later a prepared commercial ceramic clay was obtained which was slightly coarser but served almost as well. The grain size distribution of both of the clays is shown in Fig. 1.

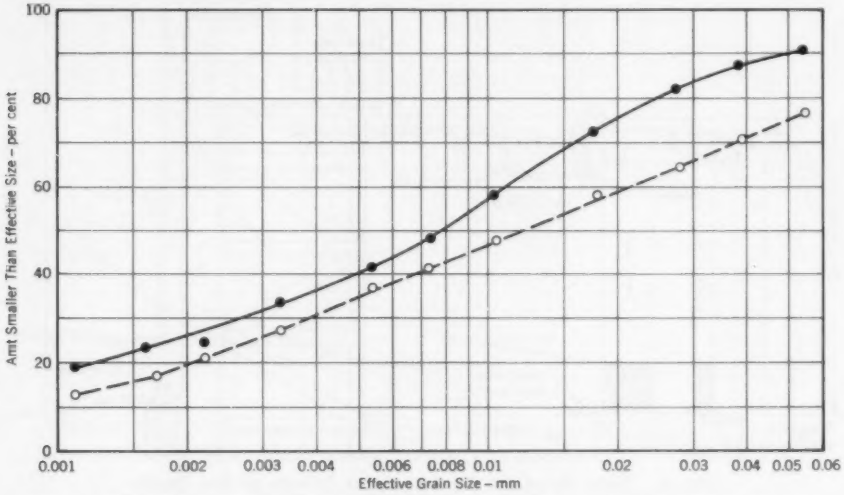

Fig. 1. Grain Size Distribution for Clays Used in Preparation of Turbid Waters

The solid and dashed curves represent prepared and ceramic clays, respectively.

The experimental filter system is illustrated in Fig. 2. Air agitation was used in an attempt to hold all particles of clay in suspension.

Bed Depth and Turbidity Removal

It was desired to determine whether or not a particular type and size of coarse-grained medium would have an optimum depth. Four depths, 7, 14, 28, and 42 in., were studied. The coarse-grained filter medium, utilized in all depths, was an uncrushed river gravel with a nominal size of $\frac{1}{4}$–$\frac{1}{2}$ in. A filtration rate of 0.1 gpm/sq ft was maintained for all filters. During this experiment the water level for the filters was maintained at 70 in. above the bottom of the filters.

Turbidity tests were periodically made on the filter effluents and on the raw water. Results of these filter runs are shown in Fig. 3. By the end of each filter run (a minimum of 145 hr) an appreciable layer of clay had deposited on the surface of the filter bed. In the filter bed depths of 14, 28, and 42 in., particles of clay turbidity appeared to have penetrated to a depth of approximately 12 in. In the shallow, 7-in. filter bed, the penetration of clay appeared to be limited only to the upper 4 in. of the bed, and the layer of clay formed on the surface of the filter was $\frac{1}{4}$–$\frac{1}{2}$ in. thick after 262 hr of operation. No loss of head was detectable on the manometer at any time during the filter runs.

The data in Fig. 3 indicate that increasing the depth of filter bed caused a general increase in the efficiency of the filter. A ripening effect was noticed in all tests, regardless of bed depth. The 28-in. bed was practically as efficient as the 42-in. bed, whereas the 14- and 7-in. beds were slower to develop filtering capacity. Even after 263 hr, the shallower beds produced slightly more turbid effluents than those obtained by the 28-in. bed. For all practical purposes, it is assumed that the beds approximating 28 in. in depth

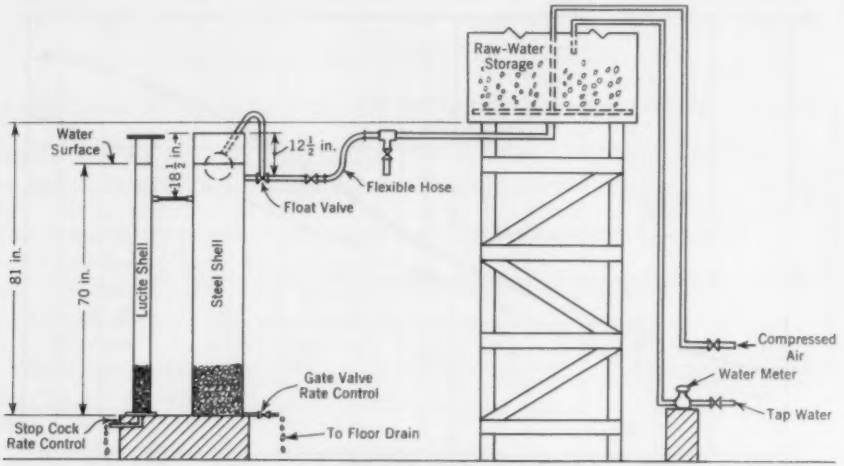

Fig. 2. Filter Setup for Studies of the Effects of Bed Depth

Compressed-air agitation was used to keep clay particles in suspension in the raw water.

are most desirable for this particular size of pea gravel. It is possible that other sizes of gravel might have other optimum bed depths and ripening periods.

Performance of Various Media

The object of another phase of the laboratory investigation was to evaluate the performance of three different types and four sizes of aggregate as coarse-grained filter media. The mineral aggregates studied were:

1. Uncrushed ¼–½-in. river gravel
2. Crushed ¼–½-in. limestone
3. Crushed ¼-in.–No. 10 limestone
4. Crushed ½–1-in. limestone
5. Lightweight ⅜-in.–No. 8 aggregate produced from expanded shale.

Analyses of these aggregates are shown in Fig. 4. A filter bed depth of 14 in. and a rate of filtration of 0.1 gpm/sq ft were used throughout this series of tests.

Laboratory Equipment and Operations

The equipment used in these investigations was essentially the same as that described in Fig. 2 with minor modifications. Two additional 4 in. diameter lucite shell filters were added to the system, making a total of three lucite filters interconnected to the larger steel filter shell. The raw-water level was held at 70 in. above the filter bottom in all units by a master float controller, and the effluent was adjusted individually at each filter outlet.

The artificially turbid water, prepared with ceramic clay, was employed in this series of tests. At periodic intervals,

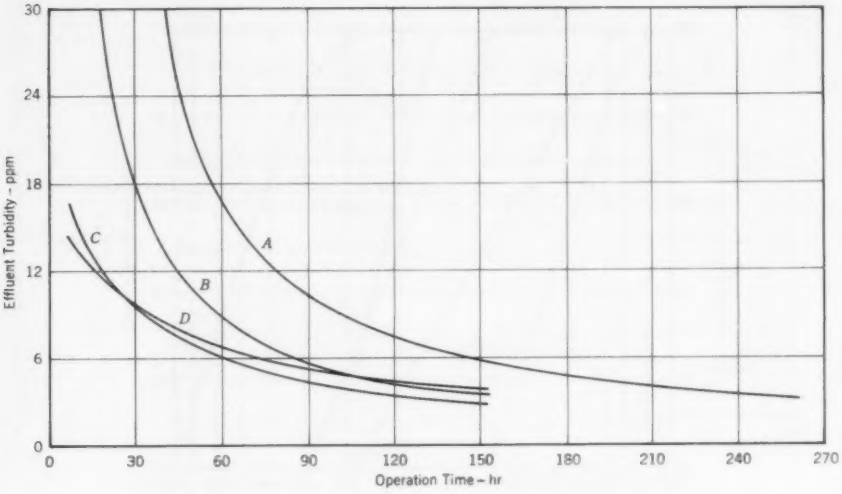

Fig. 3. Filter Performance at Various Bed Depths

Curves A, B, C, *and* D *represent 7-, 14-, 28-, and 42-in. beds, respectively. The filtration rate for all tests was 0.1 gpm/sq ft. Turbidities for the raw water were: maximum, 100 ppm; minimum, 50 ppm; average, 87 ppm.*

turbidity tests were performed on the effluent with a turbidimeter. The length of the filter run for each of the five media under investigation was approximately 210 hr, except for the unit utilizing ¼–½-in. gravel, which was studied for 424 hr of continuous operation.

Laboratory Results

From the large amount of data collected, scatter diagrams were plotted for each run and trend lines were fitted by the method of least squares. Figure 5 depicts the trend in filter performance established by the experimental series. From these graphs three things can be seen: [1] that filter efficiency usually increases as the medium decreases in size; [2] that there is an increase in efficiency due to aging, although even a 200-hr run was not sufficient to reveal the time necessary to give maximum filtering action; and [3] that, although a minor filtering effect resulting from shape or type was detectable, the variations were so small that these factors were negligible.

No loss of head was detected at any time during this laboratory test series. Heavy surface deposits of clay up to ½ in. on top of the medium were discernible, and penetration of silt was noted throughout more than half the bed of aggregate.

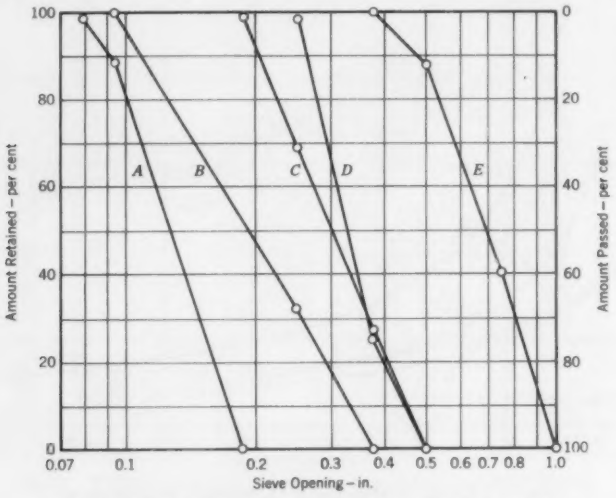

Fig. 4. Grain Size Analysis of Coarse-Grained Media

The curves represent data for media of the following grain size and uniformity coefficients (in that order): A, ¼-in.–No. 10 limestone, 1.50; B, lightweight ⅜-in.–No. 8 aggregate, 2.08; C, ½–1-in. gravel, 1.61; D, ½–¼-in. limestone, 1.35; E, 1–½-in. limestone, 1.60.

Effect of Water Depth Above Bed

The effects of water depth above the filter bed on the operational efficiency of the filter were investigated. Experi-

mental depths of the raw water layer on top of the media were 12, 28, and 78 in. The equipment was that used in the previous study, modified so that three different levels of raw water could be steadily maintained on each filter unit (Fig. 6). The coarse-grained medium was a 14-in. layer of $\frac{1}{4}$–$\frac{1}{2}$-in. river gravel. The artificially mixed turbid water was made from ceramic clay, coarser, it might be assumed that the increase in efficiency with greater surcharge is attributable to preliminary settling and agglomeration of particles before filtration.

Pilot Plant Investigation

With the completion of the small-scale laboratory investigations, pro-

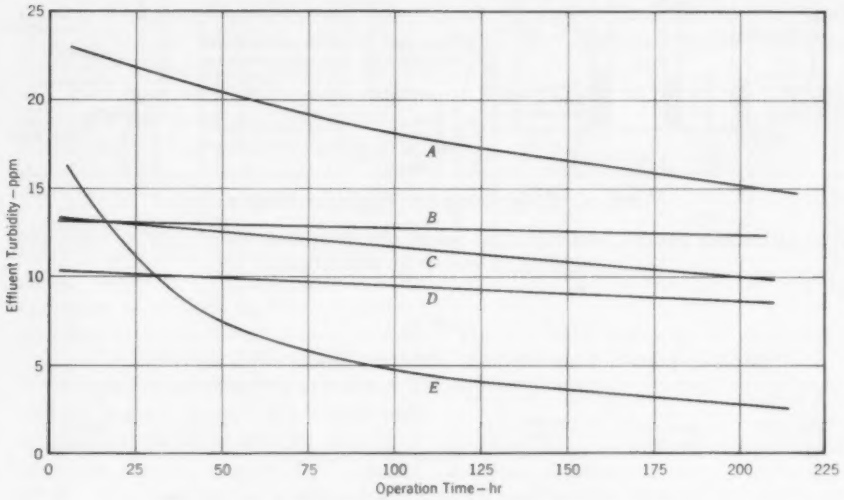

Fig. 5. Performance of Various Coarse-Grained Media

Curves A, B, C, *and* D *represent, respectively, 1–½-in. limestone, ½–¼-in. limestone, ½–¼-in. gravel, lightweight, ⅜-in.–No. 8 aggregate, and ¼-in.–No. 10 limestone. Raw-water turbidities were: maximum, 95 ppm; minimum, 70 ppm; average, 85 ppm.*

and a filtration rate of 0.1 gpm/sq ft was retained throughout all runs.

Figure 7 shows the trend lines developed from scatter diagrams for the three depths of surcharge investigated. There was an increase in efficiency with an increased depth in the layer of water over the filter bed. Because the settled particles on the surface of the medium in the unit with the 78-in. surcharge appeared to be thicker and longed studies of coarse-grained media were made under field conditions. The desired information included:

1. The effects of seasonal variations on filter performance
2. The length of filter runs attainable without excessive loss of head
3. The extent of turbidity removal with coarse-grained media
4. The efficiency of the filter in the removal of bacteria.

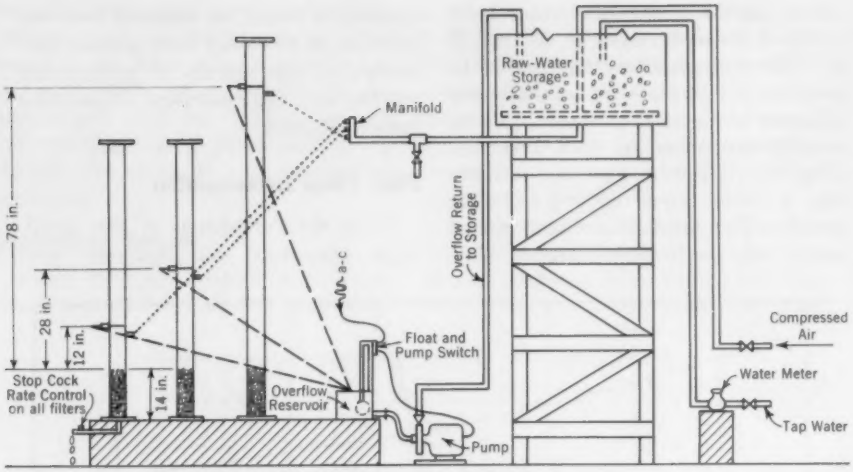

Fig. 6. Filter Setup for Surcharge Studies

The dotted and dashed lines represent piping for flow from raw water to filter and overflow to reservoir, respectively.

TABLE 3

Bacteriological Examinations by Membrane Filter Method, April 1958

Sample No.*	Day of Month	Volume Filtered *ml*	Bacteria Count		Avg Count per 100 ml	Reduction *per cent*
			Sample 1	Sample 2		
1R	3	1	238	208	22,300	
2R	3	0.1	26	27	27,000	
3F	3	1	76	164	12,000	46
4F	3	0.1	5	10	8,000	
5R	15	1	251	211	23,000	
6R	15	0.1	23	35	30,000	
7F	15	1	63	49	5,500	76
8F	15	0.1	7	12	10,000	
9R	17	1	150	129	14,000	
10R	17	0.1	18	17		
11F	17	1	48	52	5,000	64
12F	17	0.1	10	8		
13R	26	1	130		13,000	
14R	26	0.1	15			
15F	26	1	55		5,500	58
16F	26	0.1	10			

* Raw (R) or filtered (F).

Previous investigations were all made on small-capacity filters, and variables were closely controlled. In the light of the results of laboratory investigations it was decided to install a pilot filter plant of sufficient size and capacity to simulate full-scale field operations.

The filter system used in this operation is shown schematically in Fig. 8. A circular steel tank 43½ in. in diameter and 48 in. high served as the filter shell. The ¼–½-in. river gravel medium was placed to a depth of 16 in. and the raw-water level was maintained 28 in. above the surface of the gravel by a float controller valve in the ¾-in., gravity-fed, influent pipe. The rate of flow through the filter was manually controlled by a ½-in. gate valve at the filter outlet. To provide visual inspection of the filter under operating conditions, a 4-in.–diameter, transparent-lucite filter was operated in parallel with the pilot filter.

The pilot plant used water from a surface impoundment. The filter was located on the downstream face of a dam that has a maximum height of 50 ft. The lake has an estimated surface area of 15 acres. Raw water was supplied by a pipe driven through the dam, and the intake is approximately 11 ft below spillway level. The water entered the filter under a static head of 15 ft. During the summer of 1957, just before filtration experiments began, the turbidity averaged 65 ppm (silica scale) and ranged between 40 and 100 ppm, depending on rainfall. The medium employed was smooth, rounded river gravel with nominal size ¼–½ in. and a uniformity coefficient of 1.61.

Filter operation was commenced on Aug. 15, 1957, and the filter is still in continuous operation at the date of this report (August 1958). Analyses have been completed through the first 200 days of operation. To keep close watch on early trends, rate checks and turbidity measurements were made once or twice daily. As the operation stabilized, readings were taken only once or twice weekly.

Although the pilot plant performed almost without attention, there were rate control difficulties at the small lucite filter because the control stopcock was clogged by minute particles. Operation of the lucite filter was also stopped by freezing.

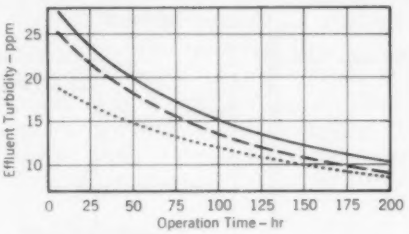

Fig. 7. Filter Performance at Various Surcharges With ½–1-in. Gravel

The solid, dashed, and dotted curves represent, respectively, 12-, 28-, and 78-in. surcharges. The bed depth was 14 in. and the filtration rate was 0.1 gpm/sq ft. Raw-water turbidities were: maximum, 100 ppm; minimum, 30 ppm; average, 79 ppm.

Turbidity Removal

Reduction in turbidity has been the primary measure of filter efficiency. During pilot plant operations the lake water varied from 56 per cent below to 47 per cent above the average of 68 ppm. With almost daily fluctuations in raw-water turbidity, it almost necessarily followed that the turbidity

of the filtrate would vary. These variations are shown in Fig. 9. Conclusions drawn from the study thus far are: [1] that aging of the filter has a marked effect upon the efficiency of turbidity removal; [2] that the efficiency of turbidity removal is inversely proportional to raw-water turbidity; and [3] that seasonal variations are minor except for indirect effects of ice cover and periods of intense rainfall.

The laboratory study that had indicated an aging effect (Fig. 10) was

bidity, 92 per cent, occurred at a time when the raw-water turbidity was near a minimum (after 5 months of operation). Conversely, the minimum reduction in turbidity, 36 per cent, occurred during a heavy algae bloom after less than a month of operation. The inverse relationship is shown in Fig. 8.

Climatic conditions affected filter performance only indirectly. The major factor was rainfall and its resultant surface runoff, which contrib-

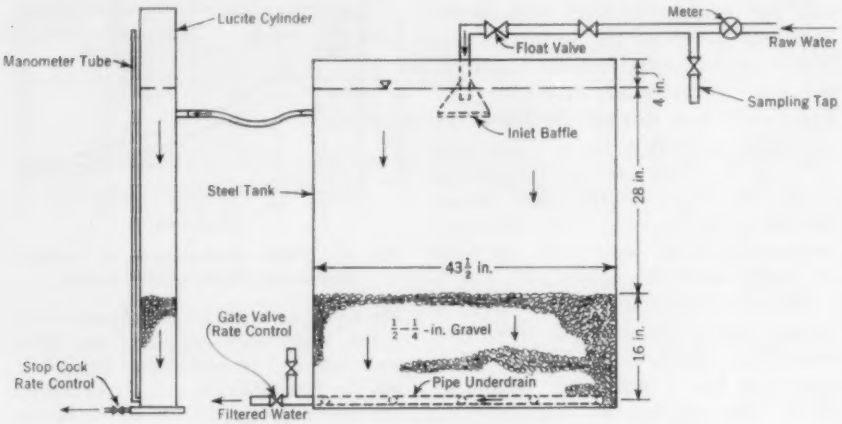

Fig. 8. Schematic Diagram of Pilot Plant

This pilot installation was built to simulate full-scale field operations.

borne out quite conclusively by the field tests. The action of filter improvement continued with operation time until a filter effluent turbidity of 5–7 ppm was approached (compared to an average raw-water turbidity of 68 ppm).

Contrary to indications of previous filtration studies, the percentage removal of turbidity decreased as the raw-water turbidity increased. For example, the maximum reduction in tur-

uted to increases in and changing types of lake turbidity. Most increases in raw-water turbidity were the result of rainfall. Exceptions were two algae blooms for which the removal by filtration appeared to be rather ineffective. An ice cover over the lake in February caused the turbidity to drop to nearly 30 ppm. The filter maintained a high efficiency in removing fine, nonsettleable solids. Although artificial heat was not supplied

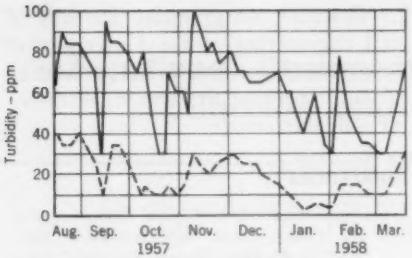

Fig. 9. Turbidity Variations at Pilot Plant, Aug. 15, 1957–Mar. 19, 1958

The solid and dashed curves represent raw and filtered water, respectively. Raw-water turbidities were: maximum, 100 ppm; minimum, 30 ppm; average, 68 ppm. Filtered-water turbidities were: maximum, 40 ppm; minimum, 3 ppm; average 24 ppm.

there was no tendency for ice formation within the large filter.

Bacteria Removal

No bacteriological examinations were conducted until after the filter had been in operation for about 7 months, and there is therefore no complete record throughout the experiment. Table 3 lists the total count examinations made Apr. 4–27, 1958. The membrane filter technique for total counts of bacteria per 100 ml of water was used throughout. The average reduction in bacteria with filtration was 61 per cent for a recorded range of 46–76 per cent. for a recorded range of 46–76 per cent. There was no attempt to make differential bacteria counts.

Head Loss

One object of these experiments was to determine the length of filter run that could be maintained before rate interference (head loss) could be attributed to clogging. Although the filter was operated for nearly a year, no measurable head loss developed. Determination of this factor depends upon continued observation and study.

Appearance of Filter

Because the large tank filter was still in operation, it could not be disturbed in order to examine the filter media. The conditions in the parallel transparent lucite filter should be representative of those in the pilot filter. A 1-in. layer of silt and decayed organic matter (mostly algae) has formed on the surface of the filter medium. This material has a dark, grayish-brown color and extends to a depth of 6 in. into the gravel. Particles of silt were found throughout the entire depth of medium and there were only slight accumulations at the bottom.

Conclusions

Evidence from the pilot plant study over a 7-month operating period has shown that the turbidity of normal surface waters may be substantially reduced by filtration, without prior treatment, through a coarse-grained material such as pea gravel. With a 16-in.

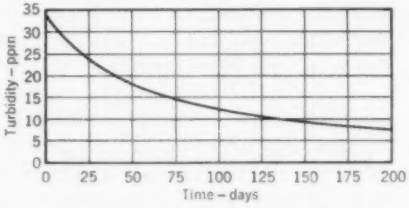

Fig. 10. Effect of Operation Time on Turbidity, Pilot Plant

The total time for the test period was 215 days. Filtered-water turbidities were: 40 ppm; minimum, 3 ppm; average, 24 ppm.

bed of $\frac{1}{2}$–$\frac{1}{4}$-in. gravel, at an operating rate of 0.1 gpm/sq ft, the average efficiency of turbidity removal is well in excess of 50 per cent and has reached 90 per cent on occasions.

Such a filter has a capacity for effective long-term operation without appreciable head loss and without need for cleaning. In this study the turbidity of the filtrate generally varied between 5 and 30 ppm, and it was demonstrated that this kind of filtration will remove at least 50 per cent of total bacteria present in normal waters. The efficiency of this filtering method is greatest in low turbidity waters where particle size is preponderantly colloidal.

Acknowledgments

This article is largely the result of investigation conducted by Nixon W. Powell, Bennie J. McCoy, and Robert L. Yeatman, all graduate students in civil engineering at the University of Arkansas, Fayetteville. Appreciation is also expressed to John F. Andrews for valuable advice.

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Functional Design of the Wayne County Filtration and Pumping Plant

Alfred W. Sawyer

A paper presented on Sep. 27, 1957, at the Michigan Section Meeting, Detroit, Mich., by Alfred W. Sawyer, Partner, Hazen & Sawyer, Engrs., New York, N.Y.

THE functional design of the Wayne County, Mich., filtration and pumping plant was assigned to the author's firm when the county project moved from the report to the design stage. Concurrently, outside consultants were retained for the detailed structural, mechanical, and architectural design and the preparation of contract plans and specifications.

A report, which outlined the basic elements of the functional design, was submitted in September 1956, and since then close liaison between all those involved has brought the plant design substantially toward completion.

Plant Capacity

The plant is designed for an initial net output of 150 mgd with provision for later expansion to 450 mgd. The initial gross plant capacity has been set at 160 mgd to provide an ample margin for plant use.

For a plant operating rate of 160 mgd, the components have the following ratings: two flash mixers, 24 sec; four flocculation basins, 40 min; four sedimentation basins, 4 hr at 500 gpd/sq ft; twenty double-bed filters, 2.56 gpm/sq ft; filtered-water storage capacity, 30 mil gal.

Certain plant elements which could not be enlarged economically or conveniently at a later date have been designed to the ultimate capacity. These include the low-lift pumping structure and some of the more important conduits. Space is provided also for additional screens, meters, mixers, chemical feeders, and high-lift pumps. Provision for economical expansion of the plant has been a very important element of the design from the selection of the plant site to the present time.

Treatment

Color and turbidity in Detroit River water is generally low and easily coagulated with alum. The Detroit filter plants apply an average alum dose of 10 ppm and the maximum monthly dose in recent years has averaged about 24 ppm. At Wyandotte, an average of 12 ppm alum is used. Conventional flocculation, coagulation, and filtration will produce a clear water, and special provisions have been made for disinfection and control of tastes and odors to insure a safe and palatable water.

Provision has been made for prechlorination, postchlorination, and dechlorination (if necessary) for long flocculation and settling times to allow ample time for the chemicals to react; and for taste and odor control with activated carbon and chlorine dioxide.

Plant Layout

Wayne County was fortunate to obtain the plant site finally chosen, as

few open areas remain that are strategically located in relation to the intake and the present and expected future system loads. Railroad service is available at the northwest side of the site and the Sexton and Kilfoil drain crosses the southwest corner. In addition, the raw-water tunnel can run on almost a straight line from the shore of the river beneath existing roads.

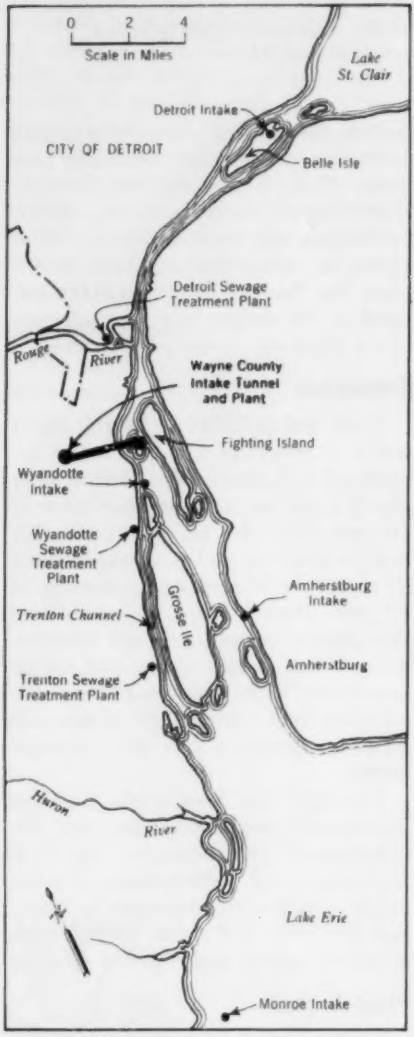

Fig. 1. Detroit River Area

Points discussed in the text are shown above.

There is rock approximately 80 ft below the ground surface, which makes possible the construction of a relatively shallow tunnel in clay from the shore shaft to the plant. A higher rock elevation or a greater distance from the shore would have necessitated a tunnel of larger diameter or one partially or wholly in rock to keep the tunnel crown below the hydraulic grade line at peak flow.

The location of the plant is shown in Fig. 1 and the profile of the 12-ft diameter tunnel is shown in Fig. 2. There is approximately a mile of tunnel in rock from the intake to shore and 3 mi in clay from shore to the plant. The intake and tunnel have already been designed and are under construction.

The plant site is relatively level. On most of the site 10 ft of firm clay overlies approximately 60 ft of soft clay. Heavy structures, such as the pumping station and chemical building, are designed for pile or caisson foundations. The basins, filters, and filtered-water storage reservoirs have been kept shallow with uniform, light loading to allow construction without pile foundations. Deep excavation has been avoided wherever possible. Filtered-water storage is above ground in steel tanks, and water is delivered from the filters to storage by means of transfer pumps. This allows more economical construction and reduces potential contamination and flotation to a minimum.

The raw-water tunnel connects to a circular low-lift caisson. Low-lift pumps deliver to traveling screens at the west end of the chemical building. The water then passes through venturi meters and conduit to rapid-mix chambers at the east end of the building.

Conduits from the rapid mix feed into four flocculating and settling basins with flow toward the east.

Return conduits between the basins bring the settled water back to four banks of filters. Filtered water is delivered to storage and thence to the high-lift pumps by transfer pumps arranged along the east side of the high-lift station together with filter washwater pumps. Filter backwash and basin cleaning water discharge to a sump between the high- and low-lift ratory. All major pumping units, including those for low lift, high lift, transfer, backwash, and drainage, are housed in one room and served by the same traveling crane. All of the drives for these pumps, as well as the traveling screens, are within sight of the control center, which is on the second-floor level at the common corner between the pumping, chemical, and filter areas. A fully equipped laboratory and administrative offices are adjacent to the control center.

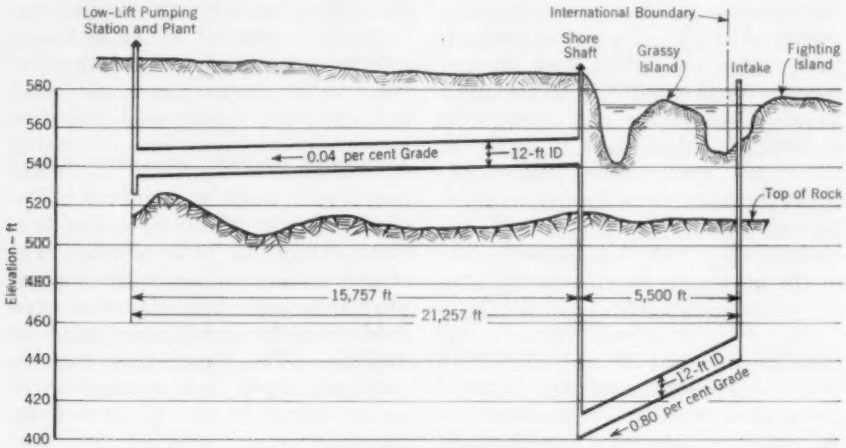

Fig. 2. Intake Tunnel Profile

The elevations and dimensions of the intake tunnel for the proposed Wayne County Plant are shown above.

stations, and drainage pumps discharge to clarifiers west of the storage tanks. Clarified water will be bled into the Sexton and Kilfoil drain, and sludge will go to drying beds or into the Moran Road trunk sewer running to Wayne County's Wyandotte sewage treatment plant.

In the arranging of the various plant units, an attempt has been made to include as many of the plant functions as possible under one roof with a centrally located control center and labo-

Close grouping of as many important plant elements as possible has resulted in rather long conduits for the settled water, particularly as the basins were made shallow and cover a large area to lower the basin surface load and to spread the foundation load. The conduits running the length of the basins have not been expensive, however, as independent basin walls were desired for maximum articulation of the structures and the two conduits employ these double walls as their

sides. Close grouping will help to reduce the length of chemical-feed lines, most instrumentation connections, and sampling lines. Also, fewer operating personnel can do a more efficient job.

Ample space remains to the north for future expansion with units the same size as those in the first stage, or of a different size if desired. There would be no conflict with, or crossing of, operating parts of the plant.

Low-Lift Pumps

The low-lift substructure is a circular concrete caisson with an inside diameter of 65 ft. The tunnel connects to a center well which feeds to four outer wells through 8-ft square sluice gates. Each of the four outer wells is large enough to take two vertical, mixed-flow pumps with their motors above the pump room floor at an elevation of 612 ft. Each pump will discharge into a collecting channel. The discharge piping is so arranged that no valving is needed.

Six pumps are planned for the initial installation, one at 20-, two at 40-, and three at 60-mgd capacity. Larger pumps will be added in the future as the plant expands for a total installed capacity of 580 mgd.

The possibility of surge in the low-lift caisson was given special consideration and was one of the factors which determined the caisson diameter. As mentioned previously, the raw-water tunnel is fairly shallow and the allowable range of water levels in the caisson to prevent dewatering the tunnel or flooding the pump room floor is 25 ft above high river level and 20 ft below low river level. The dampening effect of storage in the caisson will keep surges at the ultimate flows within these limits. It should be noted that the surge cycle will be 10–15 min and that the turning of pumps on or off in phase with the surges could cause trouble. On the other hand, proper timing of pump operation could be used to damp surges.

Screens

Three traveling screens are provided at the outlet of the collector channel that surrounds the low-lift pumps. The screens are 10 ft wide with 15 ft of submergence and have $\frac{3}{8}$-in. wire mesh. Two bypass channels with long overflow weirs are provided to function if the screens become clogged suddenly by a school of fish or by ice.

Screening was considered ahead of the low-lift pumps, but a very deep and expensive screen well and deep screens would have been necessary. In addition, the automatic-bypass feature would have been difficult ahead of the pumps, where there can be a wide change in water levels. The screens as planned can be lifted in one piece from their channels by an overhead crane for quick maintenance or overhaul. The river intake has bar racks with $3\frac{3}{4}$-in. clear openings which is considered ample to protect the pumps.

Meters, Chemicals, and Mixing

Venturi meters are provided in two pipes running from the screens to the mixers. These will pace the raw-water chemical feed. Chemical delivery can be made by either rail or truck, and liquid alum and activated carbon slurry can be stored in underground tanks. Chlorine delivery will be in tank cars. Provision is made also for limited storage of bagged alum and activated carbon, which could be fed into the storage tanks if bulk shipments were delayed, and for ton containers of chlorine.

Sodium chlorite for chlorine dioxide generation will be stored in drums. Sulfur dioxide for dechlorination, when needed, will be stored in cylinders, and ammonia will be kept in above-ground tanks. Space is provided for fluoride and coagulant-aid equipment if it is desired to add them in the future.

Standard chemical feeders are planned with circulating pumps and rotary-dip feeders for alum and carbon. Some feeders smaller than ultimately will be required are planned in order to give close regulation of chemical feed during the gradual buildup of plant load.

Two rapid-mix chambers, each with baffles above and below, and impeller-type mixers are planned.

Flocculation and Settling Basins

Each of the four flocculating basins is 135 ft wide and 85 ft long with a 16-ft water depth. Each has five transverse compartments formed by baffle walls and each compartment has six flat-blade, impeller-type turbine wheels mounted on shafting running the width of the basin with a V-belt, variable-speed drive at one end. Six valved inlet ports discharge toward baffles opposite the impellers and six ports are provided in each of the baffle walls. Both reel and impeller flocculators were considered. The latter type was chosen as it is believed that it will give more uniform mixing. In addition, the low starting torque of the impeller type is a distinct advantage over the inertia and drag of large-reel installations.

It is interesting to note that tests made on Detroit River water showed the usual tapered flocculation or gradual lessening of turbulence imparted to the water as it passes through the basin was less effective than a continued high turbulence with a short period at a reduced rate at the end. With individual drives on each of the five impeller shafts, maximum flexibility of tapered- or constant-rate flocculation can be realized. On wet-dry installations, V-belt drives have given good service in a number of plants and were considered preferable to chain drives.

Flocculated water will be distributed by a checkerboard baffle into the settling basins, which are 575 ft long and have a 12-ft average water depth. There are an end weir and six gated outlets in each basin. No sludge scrapers are included in the original installation, but provision is made for them in the first 175 ft of each basin to be added at a future date. Drains, high-pressure water pumps, and hose connections are provided for drawdown and flush operations.

Inlet and outlet conduits are designed to balance the flow across the basins. Additional balancing may be obtained by adjusting butterfly valves on the six inlet ports in each basin.

Filters

The twenty 8-mgd filters are ranged in four banks on two facing galleries. Each filter is divided into halves by a central gullet running from front to back. Influent and drain are at the back with valves in the gullet. Effluent, wash, and surface wash connections are at the front. There is a separate effluent conduit for each bank of filters. Each filter half has a central manifold beneath the floor with effluent and wash connections arranged so that half a filter is washed at a time.

Filter bottoms are to be of the Leopold or Wheeler type, and 20 in. of sand with an effective size of 0.54 mm is planned. Of the various types of wash water gutters studied, precast concrete appears most economical.

Filter Control, Transfer, and Backwash Pumps

Each concrete effluent header, serving five filters, will discharge over a sealing weir into an equalizing chamber. Filter effluent piping connecting to the header has sufficient run for the installation of conventional rate controllers, but none is planned for the original installation, as rate control will be accomplished by pumping rather than throttling. An orifice meter to measure and limit individual filter output will be provided on each effluent, however.

Each equalizing chamber will be served by a vertical transfer pump capable of delivering up to 40 mgd. Because both head and delivery must cover a wide range, the pumps will have variable-pitch impellers or variable-speed drive.

In effect, each transfer pump will act as a single rate controller for a bank of five filters. Any rate setting on a master control tied to a meter will vary pump speed or impeller pitch to compensate for increased loss of head through the filters or changing water level in the reservoirs.

When one of the five filters is out of service for washing, the pump will cut back to 80 per cent of delivery. Constant-rate filtration will result if all five filters are washed in quick succession. If variable-rate filtration is desired, the filter washes will be staggered. Comprehensive tests run in an existing plant as part of the design work have shown that better efficiency and a better-quality effluent were produced when the filters were operated on a variable-rate basis.

Two similar pumps will be used for filter backwash, taking water from the high-lift pump suction header. A program control, on which the desired wash cycle is set, will control pump delivery.

Flexibility will be provided so that any transfer pump can discharge either to the reservoirs or the high-lift suction header and the filter backwash pumps can be used as standby transfer pumps. In addition, flow can be diverted directly to the high-lift pumps from the equalizing chambers in emergency situations.

Actually, each of the four banks of filters can be operated at different rates or in a different manner. This will allow parallel testing of both constant-rate and variable-rate filtration at different filter loadings, and the information gained can be of great value in planning future extensions of the plant.

For initial operation it is planned to pass all filtered water through the reservoirs before it goes to the high-lift pumps. This requires larger than normal conduit capacity, but provides maximum detention for any postfiltration treatment.

High-Lift Pumps

The high-lift pumps will be vertically mounted, dry-pit, centrifugal pumps with positive head on the suctions. Two 20-, one 25- and four 55-mgd pumps will be included in the initial installation with space provided for two additional units and the replacement of original small pumps with larger units.

Although a maximum discharge head of 90 psi will be required to meet peak demands, much less will be sufficient most of the time. An extensive evaluation study of the high-lift pumps has been made to determine the best pump sizes and characteristics in relation to both the initial and future distribution system and load.

Instrumentation and Control

The main instrument panel for the plant will be in the control room which overlooks the main pump room and is adjacent to the laboratory. The panel will be of the full graphic type with indicating lights for all pumps, rapid mixers, flocculation basin drives, and waste water clarifier drives. High- and low–water level alarm lights will be provided for critical water levels in the plant and there will be a toxic and combustible gas detection and alarm system.

Miniature strip chart recorders will be provided for low-lift, transfer, wash water and high-lift pump flows; plant discharge header pressures; and residual-chlorine, turbidity, and pH readings. Dial indicators will show totalized flows and water levels throughout the plant.

The Wayne County distribution system covers a wide area and includes two pressure zones. There are a number of system storage tanks and booster stations. Instruments for telemetered information from the distribution system will be mounted on one end of the main panel so that the control room will be the nerve center for both the system and the plant.

A separate weather panel in the control room will record wind velocity and direction, barometric pressure, outside temperature and rainfall. This information will be helpful for anticipating system loads.

Other control panels in the plant include one on the main motor floor adjacent to the transfer and wash water pumps. The latter will contain indicators for water levels and rates of flow for each bank of filters, wash water pump program control, selector switches, indicating lights, and alarms.

Main-plant flows, water levels, and pressures will be indicated on small panels adjacent to the main-pump switchgear and in the operator's office.

Filter valves will be controlled by hydraulic switches on an operating console at each filter and there will be position-indicating lights for each valve. The wash water pump will be started by a pushbutton at the console and will run through the backwash cycle automatically in accord with a preset program control. Most of the instrumentation and control in the plant will operate on pneumatic systems. Manual setting of chemical feed rates is planned and, aside from transfer, wash, and drainage pump controls, very little automatic equipment will be used. Basically, the plant will be balanced hydraulically, rather than mechanically.

Sampling pumps will deliver continuous samples to the laboratory from all stages of the treatment process.

Conclusion

Functional and economical construction together with efficient and flexible operation have been kept in the forefront throughout the plant design. In addition, the plant can be expanded up to its ultimate capacity of 450 mgd at low cost and with no interruption of operating units.

From the control center and adjacent laboratory, all operations will be coordinated as necessary to operate the plant efficiently and produce a water of high quality.

Water Reuse in Texas

Earnest F. Gloyna, W. R. Drynan, and E. R. Hermann

A contribution to the Journal by Earnest F. Gloyna, Assoc. Prof., and W. R. Drynan, Research Engr., both of the Univ. of Texas, Austin, Tex., and E. R. Hermann, Industrial Hygienist, Humble Oil & Refining Co., Baytown, Tex.

THE present status of water supply and its role in the future of Texas has been a frequent subject of analysis and report. Almost all the reports have emphasized overall quantitative need; but only recently has awareness developed of specific regional needs in Texas for more water of a desired quality. It is also recognized by some that the reclamation of water by reutilization will be an important factor in the complete development of the natural resources of Texas—and rightly so, for the utilization of usable waste waters is indeed a feasible and necessary part of the overall water economy.

In the past a hydrologic study of a river basin was sufficient to establish the adequacy of a surface supply. Nowadays, however, quality considerations are of great importance, and an effective water evaluation program must even consider the quantity and quality of used water, including waters that have been reused several times.

Requisites of Good Planning

In the overall planning of a water utilization program, three steps are worthy of consideration: [1] to determine the amount of water that will be necessary for the accomplishment of a specific task; [2] to establish the sources from which the water can be obtained; and [3] to make quality, rather than quantity, evaluations.

To support the estimates of future demands, it is customary to assume that water of required quantity and quality will be available to support the full development of the other available natural resources. This assumption is necessary because the water demands of industry and associated urban developments can only be forecast after the availability of all raw materials is known.

In Step 2, above, the engineering problem is well defined, in that the actual sources of water are limited. The problem is largely one of efficient recovery and integration of known data into an overall development. Water supplies are derived from surface runoff, which results from precipitation, from ground water, which accumulates as a result of both precipitation and percolation, and from used water. It is assumed that the mapping of ground water reservoirs and surface hydrology studies will continue. At least the methodology of finding water is well established. It is much more difficult, however, to trace the source of a water and describe its identity and past history. After water has been used, most

of it returns to nature as surface or ground water, and used-water analyses must therefore be included as part of the comprehensive picture.

As soon as the water reuse pattern develops to a significant degree the problems of reclamation become more complex, and more factors require consideration. Some of the more important topics to be given consideration in a comprehensive reuse program are:

1. The methods by which water resources may be developed
2. The factors influencing future waste water quantities
3. The criteria for quality evaluations of water that will be reused
4. The economic and technical aspects of water reuse
5. Public opinion and its effect on water reuse
6. The administrative controls necessary for a complete water reuse program
7. Possible legal problems that could arise from a water reuse program.

In the light of these considerations, statistics on waste water in Texas have been gathered and extrapolations have been made of future development. These estimates of domestic and industrial waste are based on a programed development of all the natural resources, including water. A long-term estimate such as this is necessarily uncertain because of the possibility of unforeseen economic pressures resulting from conditions outside the area.

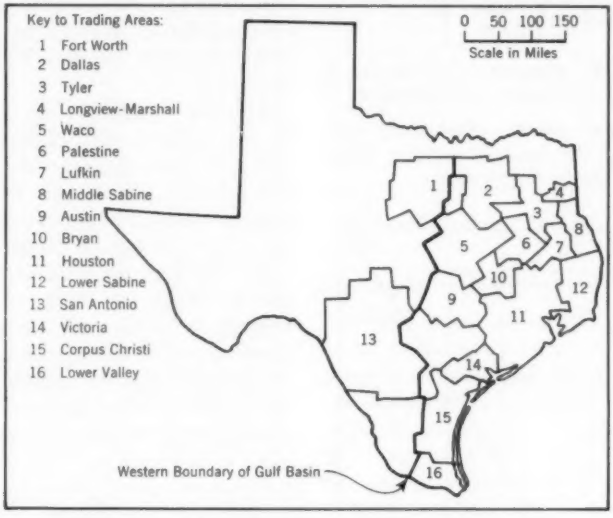

Fig. 1. Trading Areas of the Texas Gulf Basin

In the illustrations that follow all references to these trading areas will be made by number, as keyed above.

Project Area

The project area encompassed by this investigation (Fig. 1) includes 97

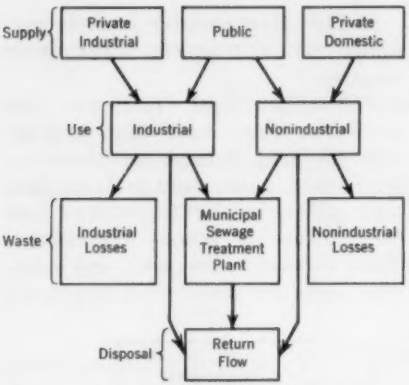

Fig. 2. Uptake, Utilization, and Return of Water to the General Environment

The simplified scheme diagramed above was used as the basis for tracing water use in the studies.

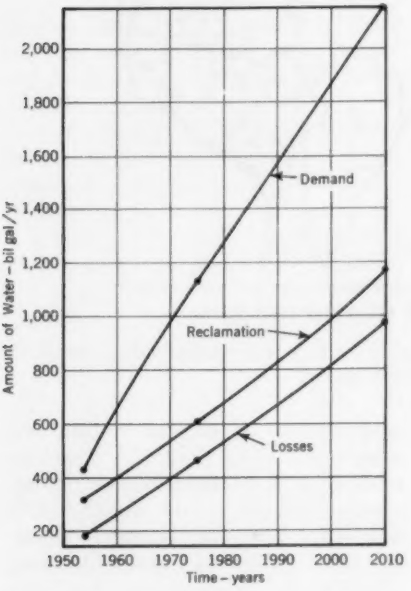

Fig. 3. Demand, Reclamation, and Losses for Survey Area

The curves are based on data provided by application of the scheme in Fig. 2.

of the 254 counties in Texas. The project generally includes the eastern and Gulf Coast sections of Texas; specifically, an area east of a north-south line including Denton, Travis, Bexar, and Hidalgo counties and south of an east-west line, including Denton, Wood, and Harrison counties. The entire eastern coastline is included.

The project area includes most of the state's natural resources. About 30 per cent of the total land mass is included; and 70 per cent of the present population resides in this area, which includes the state's five largest cities.

Climatic conditions are as variable as the area is vast (550 × 200 mi). The area studied in this survey receives the greatest rainfall in Texas. The extreme eastern portion of the area receives an average of about 50 in. per year, whereas the western portion receives 20–30 in. Rainfall decreases roughly 1 in. for each 17 mi of westward travel. Evaporation rates increase from east to west in about the same ratio as the decrease in rainfall. During 1954, a very dry year, the annual evaporation at Nacogdoches, on the eastern side of the area, was about 45 in.; near San Antonio, on the western side, it was about 65 in. during the same year. The mean annual temperatures range from about 65 to 75°F. The eastern flank has several large national forests, and the southwestern area is potentially the largest winter garden section in the United States. The growing season ranges in length from 240 to 300 days per year. Of the twelve major river systems in Texas only two do not flow through this area. Most of the ground water reservoirs are also found in the project area.

Industrial activities in Texas are well diversified. There are extensive deposits of gas, oil, uranium, clay, graphite, salt, sulfur, low-grade iron ore and coal, limestone, and oyster shells.

From a water reuse point of view, Texas has one of the most complete sewage treatment systems in the United States. The only city of more than 60,000 population that does not have a sewage treatment system is located on the Gulf Coast. Of the total population presently served by a sewage collection system, only 80,000 Texans do not receive the benefits of sewage treatment. There are over 450 municipalities with sewage treatment plants in Texas. Treated used water is currently being used for everything from irrigation to boiler makeup water.

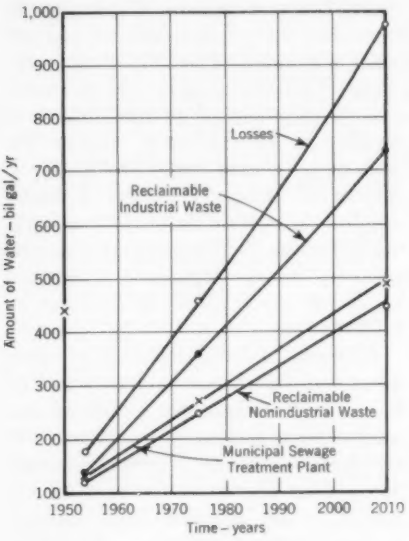

Fig. 4. Waste Water Distribution, 1950–2010

As can be seen from the slope of the plots, municipal quantities show a distinct lag behind industrial waste water.

Organization of Study

Techniques used in this research are summarized in the following three steps:

1. Sixteen trading areas (Fig. 1), as defined in a previous report (*1*), were used as basic subareas. Wherever a trading area extended beyond the overall project area, the outside portions were not considered.

2. Industrial wastes for the trading areas were subdivided into nine categories. Each category represents wastes from a major industrial group.

3. Resource data on wastes were obtained from files of various state agencies, personal contacts, questionnaires, and an extensive literature survey.

Demands and Waste Water Availability

As a necessary basis for the study reported herein, a simplified scheme of accounting for a portion of the hydrologic cycle has been developed. The paths of water from supply, to usage, to wastage, and, finally, to disposal and return flow are traced categorically. The overall scheme is diagramed in Fig. 2.

Quantitative synthesis and projection of these basic data were used to obtain the water volumes for each water survey area. Such a summary is shown in Fig. 3. The anticipated fivefold growth in total supply required for the project area is especially noteworthy. In 1954 the nonindustrial requirements were 51 per cent of the total demand as compared to 49 per cent for industrial requirements. By 1975 the industrial requirements will probably be around 53 per cent of the

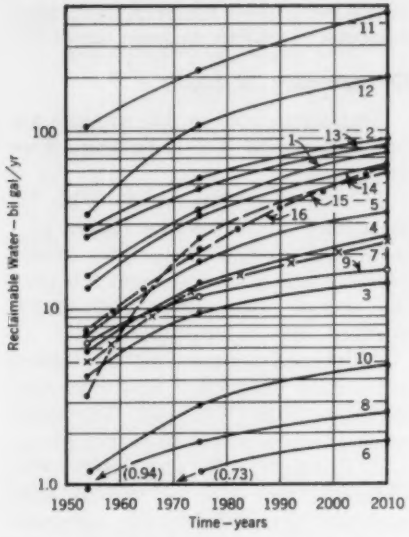

Fig. 5. Reclaimable Water According to Survey Area

The numbers of the curves refer to the key of Fig. 1. As can be seen, most of the areas will maintain their relative starting positions, with the exception of 16 (Lower Valley), 4 (Longview-Marshall), and 7 (Lufkin).

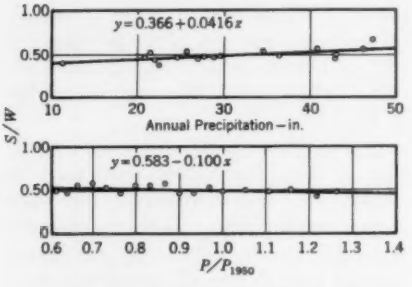

Fig. 6. Relationships of $\frac{S}{W}$ Ratio to Precipitation and Population, Austin, Tex.

The data plotted represent the years 1938–55. The 1950 population (P_{1950}) was 132,459.

total, and the nonindustrial requirements will drop to 47 per cent. It has been estimated that the total reclaimable waste water available in 1954 was about 263 bil gal; by 1975 this volume should be about 600 bil gal.

It is also of interest that privately owned water systems supply more water than the publicly owned supplies. In 1954, when the total water demand was about 444 bil gal, slightly more than half of this demand (52 per cent) was met by privately owned supplies. This was largely due to extensive development of private industrial supplies in the Houston, Lower Sabine, and Victoria areas, and to development of privately owned domestic supplies in certain larger municipalities. It has been estimated that the privately owned supplies will account for 55 per cent of the total supplies by 1975.

Accounts of the distribution of waste water components are presented in Fig. 4, in which reclaimable industrial and nonindustrial wastes are compared with anticipated losses or product consumption. Also shown is the amount expected to be handled by municipal sewage treatment plants. Municipal wastes are of particular interest because of their reclaimability and location. In 1954 about 135 bil gal of municipal waste waters were treated by municipalities, and it is expected that by 1975 this quantity will approach 275 bil gal per year. All conditions remaining the same, the sewage treated by municipalities during the year 2010 might be as much as 500 bil gal per year. Nevertheless, the municipal quantities show a relative lag behind the industrial waste water, which is not added to municipal plants. The reclaimable industrial waste waters not

put through municipal plants in 1954 were about 122 bil gal, and it is anticipated that these wastes will increase to about 326 and 674 bil gal per year by 1975 and 2010, respectively.

Four of the sixteen water survey areas, Houston, Lower Sabine, Victoria, and Corpus Christi, presently provide about 80 per cent of the reclaimable industrial waste water. It is expected that relative waste contributions will remain constant with time. By 2010, however, it should be noted that the Lower Valley water survey area will probably rank fourth place in industrial waste water discharge instead of Corpus Christi.

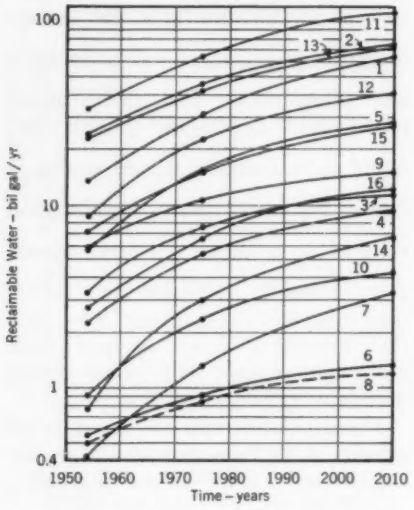

Fig. 7. Reclaimable Municipal Waste Water According to Survey Area

The numbers of the curves refer to the Key of Fig. 1.

Most of the water survey areas will maintain their relative positions as to total reclaimable water. As shown in the semilogarithmic plot in Fig. 5, most of the areas will maintain their respective starting positions. The exceptions are the Lower Valley, Longview-Marshall, and Lufkin areas. It appears that the Lower Valley area has a chance of increasing its reclaimable water by one order of magnitude in a period of about 30 years.

Municipal Waste Water

Records of used-water quantities in the project areas are not complete. Consequently, future estimates of municipal and industrial waste water quantities had to be obtained for this study indirectly from related information.

The records of municipal waste water quantities discharged by nodal cities in the various water survey areas during 1954 were extrapolated upon to obtain estimates of municipal waste water available from each entire water survey area at that time. The basic data for developing these estimates included population projections, estimates of future water supply quantities, past records of annual precipitation, past records of public water supply quantities and domestic sewage discharges, and past records of population. The procedure is outlined as follows:

1. The ratio of the annual sewage flow (S) to the annual quantity of water supplied to the community's water distribution system (W) was computed for each year between 1930 and 1955. The resulting ratio was designated as $\frac{S}{W}$ Fig. 6).

2. A least-squares plot of $\frac{S}{W}$ versus annual precipitation in inches provided a linear equation of the form $y = a + cz$.

3. Similarly, a relationship was computed between $\frac{S}{W}$ and the ratio of the population for any one year to the population in 1950 $\left(\frac{P}{P_{1950}}\right)$. The resulting equation was of the form $y = a + bx$.

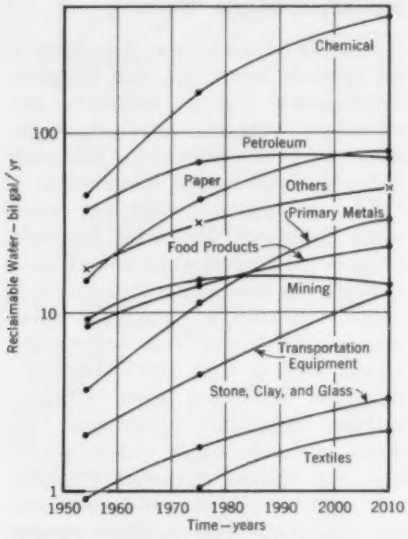

Fig. 8. Waste Water Available According to Industrial Group

The chemical, petroleum, and paper industries presently supply about 70 per cent of the available industrial waste water. This percentage is expected to grow to 80 per cent by 1975.

4. A combined form of the two above equations was derived to produce $y = a + bx + cz$. The 1954 values were calculated by using actual precipitation records. The 1975 and 2010 waste water quantities were based on mean annual precipitation and correction values having an upper limit of 2.5.

5. Finally, the quantity of reclaimable municipal waste water was estimated by multiplying public water supply values by their corresponding $\frac{S}{W}$ coefficients.

Correlation of rainfall and population data with water supply and sewage flow records demonstrates that both rainfall and population growth influence the quantity of sewage return flow. For practical purposes, the influence of precipitation upon the sewage to water $\left(\frac{S}{W}\right)$ ratio was a straight-line function for the municipalities tested, and population growth was found to be similarly related to the $\frac{S}{W}$ ratio. Increased annual precipitation resulted in a higher $\frac{S}{W}$ ratio, apparently caused by decreased lawn watering, infiltration into sewer lines, and the additional flow received from cross connections with storm water drains.

Population increase has the opposite effect. With the exception of the Palestine and Lufkin areas, population growth resulted in a lower $\frac{S}{W}$ ratio. This phenomenon was attributed to increasing urbanization around the larger cities, the undoubling of families within one household, larger lawn areas around houses, use of septic tanks in the fringe areas, lengthening of supply lines and increasing main pressures.

Quantities of reclaimable waste water are listed in Fig. 7. The Houston, Dallas, San Antonio, and Fort Worth areas are ranked first, second, third, and fourth in the quantity of waste water available from their sewage treatment plants. About 70 per

cent of the total available municipal waste water is currently located in these first four areas. It is expected that these water survey areas and their nodal cities will retain their relative positions in the project area for some time to come.

Quality

The quality of water discharged from municipal sewage treatment plants, though somewhat variable, has certain limits, and is not nearly so heterogeneous as various industrial waste waters. Municipal waste waters carry ionic constituents contributed mainly by the public water supply, with additional salts contributed by domestic and commercial wastes. These waste waters are almost certain to have higher dissolved-solids concentrations than the sources of supply. The chloride concentrations in the waste water are of the order of 100 ppm greater than in the potable supply. The organic fractions, which are amenable to biological treatment and thus readily removed, are not cumulative as are chlorides and other inorganic constituents.

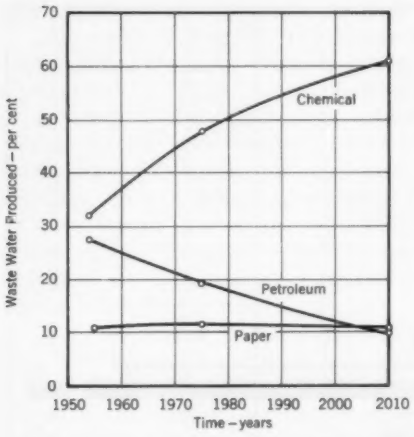

Fig. 9. Percentages of Total Industrial Waste Water Produced by Chemical, Petroleum, and Paper Industries

These three industries currently produce 70 per cent of the total available industrial waste water in Texas.

Reuse of treated municipal effluent as a source for potable water may be feasible. The record of human catastrophe caused by waterborne diseases, however, is so long and so well documented, that those who are responsible for protecting the public health and safeguarding the hygienic quality of waters are justifiably cautious about adopting such a procedure. The principle of "guilt by association" is likely to be applied by the public wherever an attempt is made to introduce water with traceable history into a drinking supply.

Industrial Waste Water

Annual industrial water usage and waste water discharge have been determined for each of the sixteen water survey areas. Using projected water demands with a breakdown of these demands by the type of industries, both present and future quantities of water were established.

Questionnaires were sent to 327 industrial concerns, each of which was reported to use more than 20 mil gal of water per year. These plants now utilize 90 per cent or more of the total quantities of industrial water used in the area surveyed.

Because all the industrial organizations could not supply the desired information, it was assumed that the ratio of waste water discharged to water intake for each reporting industrial group represented the ratio for the entire in-

dustry. It was further assumed that this ratio would remain constant for each industry during the survey period.

About 90 per cent of the total industrial water demand originates from nine industrial groups. These nine groups and their respective waste water quantities are shown in Fig. 8. The chemical, petroleum, and paper industries at present provide about 70 per cent of the total industrial wastes, and one order of magnitude in 40 years. This change is expected largely because of expected increases in primary metal activity in the Tyler, Waco, Palestine, Victoria, and Houston areas. As shown in Fig. 9, only two industries, chemical and petroleum, currently produce more than 10 per cent of the total waste water. By the turn of the century only the chemical industry is expected to be in this category.

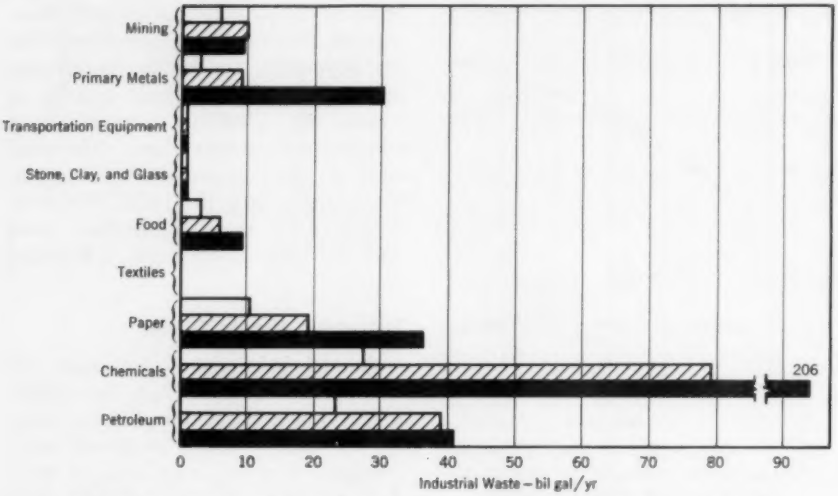

Fig. 10. Available Industrial Waste Water in the Houston Survey Area in the Years 1954, 1975, and 2010

The white, cross-hatched, and black bars represent, respectively, the years 1954, 1975, and 2010.

this percentage will probably increase to 80 per cent. By 1975 the chemical industry is expected to produce about 175 bil gal per year, which is about 50 per cent of the total industrial waste water produced. Most of the nine industrial groups will hold their respective starting positions, with the exception of the primary-metals group, whose use is expected to increase by

Only the paper industry, on a percentage basis, is expected to maintain a uniform level, and it is very likely to surpass the petroleum industry by the year 2010.

Inasmuch as the reclaimability of waste water is directly related to the type of industry in any given area, it is also necessary to show the source of the waste water. As an example of

the methodology, a bar graph is shown in Fig. 10. As can be seen, the chemical, petroleum, and paper industries discharged the majority of the industrial wastes in 1954. By 1975, the contribution from these industries will increase, but so will that from others, particularly the primary metals. It is noteworthy that, although the waste water will increase, the percentage of waste available, as compared to the total water usage, will decline as a result of extensive water reuse measures.

As noted in Fig. 11, the Houston area will only rank eleventh in the percentage of waste water produced. Compared to the Lufkin area, where paper industries predominate, all other areas have a relatively low waste availability. It is estimated that approximately 90 per cent of the total water used in the Lufkin area will be discharged and thus will once again become available for reuse.

The low return flow, 31 per cent, for the Waco area reflects the high water demands of the primary metals industry. Palestine and its environs will continue to be a nonindustrialized area. It has a predominant industry at present, namely mining. Other industries, however, such as the primary-metals industry, will produce some change in the type of waste water discharged. The decrease in waste water returned to stream in the Tyler area is largely due to the inroads of the primary-metals industry.

The decrease in the Lower Valley will be caused by a transition from the food industry to chemical manufacturing. The relatively small return flow in the Corpus Christi area in 1954 occurred because two industries used one-third of the total industrial water demand: the chemical and petroleum industries. This combination will probably continue.

The higher return flows for the Dallas and Fort Worth areas are a result of their nonconsumptive industries, such as the processing of food and the manufacturing of paper, transportation equipment, and chemicals.

Reclamation of Industrial Wastes

In the mining industry, the total return flow of waste water is only about

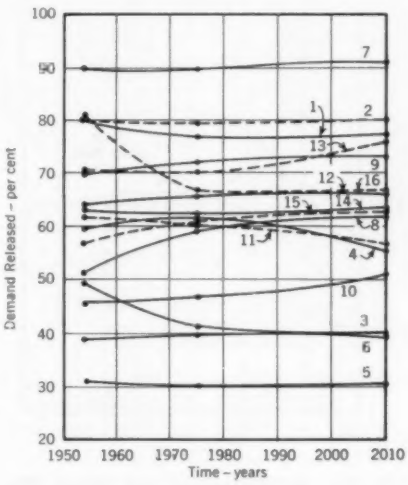

Fig. 11. Availability of Reclaimable Water According to Survey Area

The numbers identifying the curves refer to the key of Fig. 1.

44 per cent of the water intake—51 per cent of the process water and 34 per cent of the cooling-water intake. This relationship is shown in Fig. 12. Most of the available waste water arises from the production of natural-gas products, and the questionable quality of the liquid wastes from these operations makes the advisability of reclamation

doubtful. The total-solids content ranges from 700 to 70,000 ppm, but, if the sulfur industry is excluded, the average is approximately 4,000 ppm.

About 77 per cent of the water used in the primary-metal products is for cooling, and the rest is used for process. Of this, only 7 per cent of the cooling water is discharged and about 72 per cent of the process water is discharged. The waste process water contains spent acid and alkaline pickling liquors and waters from plating operations and heat-treating operations. In general, the costs of reclaiming process wastes from the metal industries will be greater than for most of the other wastes. Much of this waste water will, however, have to be treated, for reasons of health hazard before it becomes usable again.

In the transportation industry, the cooling and process water demands are about equal, and about 70–80 per cent of these waters are returned. This high return flow is due to the once-through use of cooling water by some of the larger plants and provides a large quantity of readily reusable water. Process wastes from these plants gen-

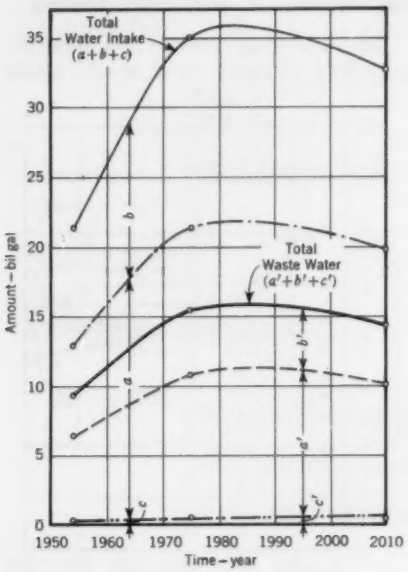

Fig. 12. Annual Intake and Waste Discharge for the Mining Industries

The symbols a, b, *and* c *represent the annual intake of process water, cooling water, and water for sanitary and other uses, respectively;* a′, b′, *and* c′ *represent the corresponding waste discharge quantities.*

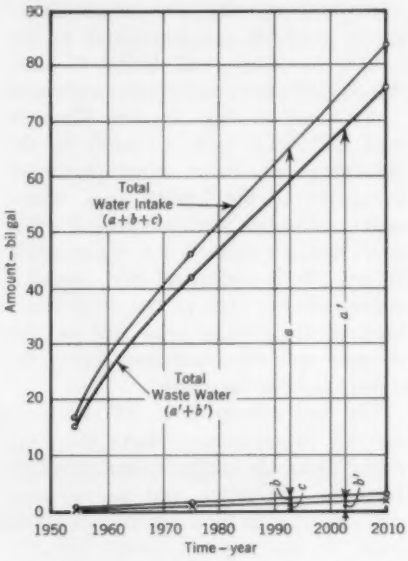

Fig. 13. Annual Intake and Waste Discharge for the Paper and Allied Industries

The symbols a, b, *and* c *represent the annual intake of process water, cooling water, and water for sanitary and other uses, respectively;* a′, b′, *and* c′ *represent the corresponding waste discharge quantities.*

erally can be treated economically and used again.

The food-processing and allied industries use about 62 per cent of their water intake for cooling and the remainder for processing. Of this amount almost all of the cooling water and 88 per cent of the process water are returned. With the exception of the recycled cooling water, the return flow can be treated and reused.

About 90 per cent of the water intake for the paper industry is discharged as liquid waste and can be reused (Fig. 13). This waste is amenable to biological treatment, as about 97 per cent of it is classed as process water.

The chemical industries (Fig. 14) require more water for their operations than other industrial groups in the project area. As 72 per cent of the total requirement is used for cooling water, it can be expected that these waters will have a high solids content. At the present time, however, about half of the chemical plants in the area use cooling water on a once-through basis. Consequently, this cooling water and the process water, which are about 66 per cent of the total process water used, are available for reuse. Waste from the plants using closed cooling systems is primarily blowdown, and the solids content is similar to that of sea water.

The largest use of water in petroleum refining is for cooling purposes. The survey of refineries in the project area shows that 57 per cent of the water intake is used for cooling, and the ratio of water usage to discharge for the entire petroleum-refining industry in the project area is about 0.67. This indicates that there is at present considerable recirculation of water within the industry. There is some room for improvement in the cooling water recycle system, but most of the recoverable water will have to come from process wastes. These latter wastes contain mostly organic substances, such as phenol and oil, and some inorganic matter, such as sulfides and chlorides. Thus, the exclusion of blowdown wastes would leave a reclaimable waste water.

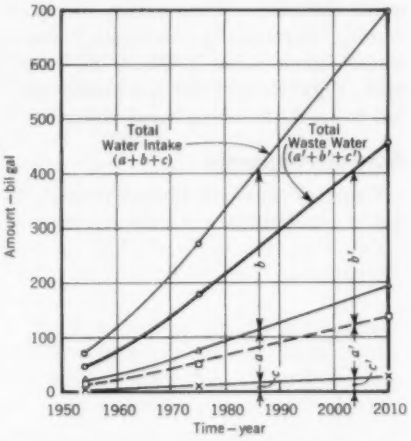

Fig. 14. Annual Intake and Waste Discharge for the Chemical and Allied Industries

The symbols a, b, *and* c *represent the annual intake of process water, cooling water, and water for sanitary and other uses, respectively;* a′, b′, *and* c′ *represent the corresponding waste discharge quantities.*

Appraisal of Reuse

When Texas reaches the critical point where future economic expansion must be planned and balanced against the quantity of water available, maximum use and reuse of all water supplies will be the critical variables.

In the next 20–30 years, it should be apparent that the most reliable and predictable source of used water will be domestic sewage. Industrial wastes as a whole will also increase, but the amount of industrial waste per unit product will decrease. The industrial waste water trend is the reverse of that for domestic wastes, which of course means that the reclaimability will be more difficult. Reclamation of waste water, particularly domestic waste water, must have a place in future plans regardless of current public opinion towards drinking used water.

Acknowledgments

Grateful acknowledgment is made to the Area Planning Office, Bureau of Reclamation, for sponsorship of the study from which the data found in this article were obtained. Particular appreciation is extended to Harry P. Burleigh, Area Engineer; Henry M. Seipt, Assistant Area Engineer, and other engineers of the Area Planning Office who helped to develop this study.

Appreciation is also extended to the many individuals, industrial companies, and municipalities who generously gave of their time and provided basic data.

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Elements of Well Construction

Raymond L. Schreurs

A paper presented on May 16, 1958, at the Pacific Northwest Section Meeting, Spokane, Wash., by Raymond L. Schreurs, Geologist, Edward E. Johnson, St. Paul, Minn.

BECAUSE water well construction involves such highly specialized fields as hydrology, geology, and hydraulics, together with the techniques that are employed in drilling and developing wells, in this brief article important aspects of the subject will have to be condensed, and less important matters eliminated. As a starting point, wells may be classified by the types of water-bearing formations or aquifers involved. There are two general classes of aquifers: consolidated and unconsolidated.

Consolidated Aquifers

Consolidated aquifers are those in which water moves through the openings between uncemented grains of sand or through fractures, solution channels, or joints. Unless a sloughing stratum is encountered, it is common practice to use only a surface casing. In sandstone—a common consolidated aquifer—water is transmitted through interconnected, uncemented pores between sand grains and through any fractures that may occur. Another common consolidated aquifer is limestone, which may have fractures and extensive channels or even caverns made during the ages by the leaching action of water containing carbon dioxide. A consolidated aquifer found in the Northwest is basalt, an igneous rock, which may have interconnected fractures that transmit water. The upper part of each flow is usually porous because of gas cavities or weathering. Shale, slate, and hardpan, and crystalline rocks such as granite, are not ordinarily considered water bearing, but they may be sufficiently fractured to yield a small quantity of water.

When a well is drilled into a consolidated aquifer, the extension of the bore hole through the aquifer is usually the only procedure needed. Results depend largely on chance and are, therefore, likely to be haphazard. If sandstone is loosely cemented, the yield may be very good, but, unfortunately, difficulty with sand pumping is also likely to occur. Well drillers working with rock sometimes use explosives in the hope of extending and increasing the number of fractures. This procedure, however, cannot always be depended on to increase yield or eliminate sand pumping. In fact, it is sometimes hazardous and may occasionally result in reduction of the sand-free yield of water.

Unconsolidated Aquifers

Unconsolidated aquifers consist of sand and gravel, with water flowing through the interstitial openings between the individual grains. Because

the grains are loose, the ability of the formation to yield water depends on the size, total area, and interconnection of these interstitial openings or pores. In order to support the loose, unconsolidated sand and gravel, it is necessary to use a well screen in the aquifer below the well casing. In contrast to rock aquifers, much can be done by the well driller to improve the yield from sand aquifers by proper methods of screening and development.

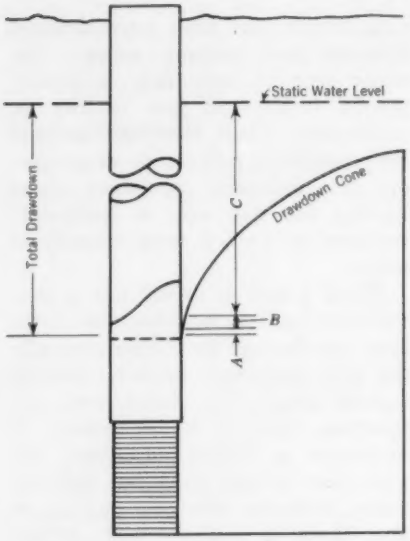

Fig. 1. Types of Head Loss

The head losses shown are: A, *in well and screen;* B, *in range of turbulent flow in aquifer;* C, *in range of laminar flow in aquifer.*

Choice of Aquifer

In some locations, conditions may necessitate the use of one or the other type of aquifer, the choice depending on the quantity or quality of water available. Frequently, however, a supply that is acceptable for both quantity and quality may be obtained from either consolidated or unconsolidated aquifers, and the selection must be based on an evaluation of the advantages and disadvantages generally inherent in each type.

Wells in consolidated aquifers have the following advantages:

1. They are less subject to the effect of subnormal rainfall, except over long periods of time.
2. They generally require little maintenance.
3. They do not require a well screen.

The disadvantages are that:

1. They are usually relatively deep and costly.
2. Yield may vary widely from one location to another in the same aquifer.
3. Water is generally more highly mineralized as depth increases.
4. Water temperature increases with depth.
5. They are subject to pollution from distant and local sources of contamination if the solution openings or fractures are large.

On the other hand, wells in unconsolidated aquifers have the following advantages:

1. They are usually not very deep and generally less expensive than wells in rock formations.
2. Their cost is relatively low per unit of water obtained.
3. Water in sand aquifers is generally lower in mineral content than in rock aquifers.
4. Water has lower temperature in shallower aquifers.
5. There is little chance of pollution because of the filtering action of sand.

Their disadvantages are that:

1. They may be more affected by subnormal rainfall.
2. They are likely to require more maintenance, particularly if not properly screened.

Water Yield

Regardless of the type of well, in the final analysis several factors determine how much water can be obtained. Over the long-term outlook, the yield depends on the replacement by rainfall or other recharge to the aquifer. Sources of recharge may be located near the well field or a long distance away, or both. When more than the amount of recharge is withdrawn, there is a decline in water level, which eventually results in excessive pumping cost and failure of the well.

The rate at which water can be withdrawn from a well in a particular aquifer depends on the hydraulic characteristics of the aquifer and the size and efficiency of the well. Therefore, the manner in which water moves through an aquifer toward the well should be considered.

Drawdown

It is axiomatic that energy must be expended whenever work is performed. The energy required for the flow of water through a pipeline, or for the flow of ground water into a well, comes from a difference in water level or water head. When a well is pumped, the level of the water is lowered sufficiently to produce enough differential head or pressure to overcome the resistance to flow through the aquifer and the well screen, and in the well. This differential head is known as drawdown. In a flowing artesian well, the drawdown is the reduction in pressure at the point of discharge. The ratio between the rate of pumping and the drawdown is the specific capacity of the well. For example, a well delivering 500 gpm with a drawdown of 10 ft has a specific capacity of 50 gpm/ft of drawdown. The drawdown is not confined solely to the pumped well; there is also a lowering of water level or pressure in the aquifer adjacent to the well. The areal drawdown picture is shaped like a cone and is sometimes called the cone of influence. As pumping continues, the drawdown and the extent of the cone of influence increase, unless a source of equal recharge is reached, such as a river or lake that is hydraulically connected to the aquifer. This continued drawdown is often not readily recognized because the rate of decline usually decreases with time of pumping.

In practice, drawdown in a well is the sum of three kinds of head loss (Fig. 1): loss encountered in the well casing and screen, loss due to turbulent flow near the well, and loss from laminar flow in the aquifer. The engineer and well driller have no control over the last, but they can do much through proper screening and development techniques to minimize the head losses adjacent to the well. In correctly screened and developed wells, these added head losses will be small in relation to those resulting from the aquifer itself, but in poorly constructed wells the additional drawdown may be very large and costly.

The scientific design of wells constructed in unconsolidated aquifers requires accurate samples of the water-bearing formation. Samples are taken as the bore hole deepens, and in some instances, they are taken from a test well drilled adjacent to the proposed site of the final well. Samples are also

taken whenever there is any apparent change in the nature of the formation, or, in any event, at some interval such as 5 ft. Representative samples that contain fine and coarse material in the same mixture as in the natural state should be carefully obtained, then divided to get a laboratory sample of about 1-pt size. This should be analyzed by being put through a series of sieves. The results should then be plotted, and the size of the slot opening required in the screen selected.

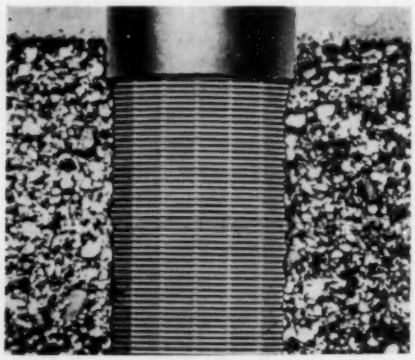

Fig. 2. Natural Gravel–Packed Well

Functioning as a filter around the well screen, the gravel pack transmits water but restrains sand particles.

Well Screens and Development

The correct well screen must be set in the proper manner so that water will enter the well in maximum quantity, free of sand. Its function is so important that the well screen is sometimes called the heart of the well. It is usually set by what is known as the pullback method. The bottom of the screen is closed with a bail plug, and at the top is a lead ring called a packer, which seals the screen to the well casing. Installation is accomplished by sinking the well casing to the desired depth, then telescoping the screen through the casing to the bottom. The casing is pulled back to expose the screen, and finally the lead packer at the top of the screen is expanded to form a sandtight seal. Other methods of screen setting may be used when conditions require, but the pullback method is most common.

Sometimes, well construction is stopped after the well screen is placed in the aquifer; the result is apt to be a poor well. Well development is not given the important consideration it deserves, perhaps because the process is not entirely understood, and the customer dislikes paying for something he does not understand or cannot see. Well development may be defined as any process used to increase the permeability of an aquifer and eliminate the damaging effects of drilling procedures. It is accomplished by removing the fine material through the well screen openings. These fines consist of any clay or silt introduced during the drilling process, as well as the finer part of the aquifer directly around the well screen.

In well development, a hydraulically graded filter is produced in the sand and gravel around the well screen. The coarsest, most uniform material is next to the screen; the finer, less uniform material away from the screen. This is comparable to the graded layers of a filter bed, without abrupt changes from one size or grading to another. Such a filter has a high capacity for transmitting water, but it will restrain any movement of the sand particles once it has been completely produced. In well-drilling parlance this is referred to as a natural gravel–packed well (Fig. 2).

Well development brings about increased capacity, stabilization of the aquifer to prevent sand pumping, and increased service life for the well. Space does not permit a detailed explanation of the methods used by well drillers to produce the desired results. It is sufficient to state that the methods are all based on establishing velocities of flow greater than those produced by the expected rate of pumping from the completed well, and combining this with vigorous reversal of flow, or surging, to prevent sand grains from bridging against each other, as generally occurs when the flow is in only one direction.

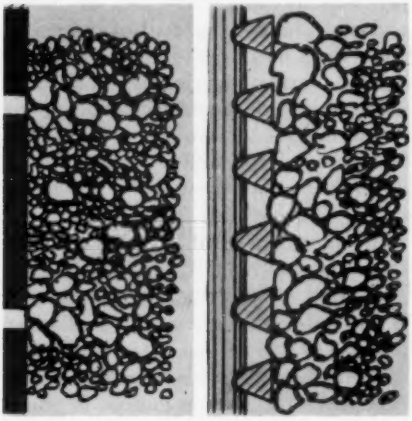

Fig. 3. Development With Slotted Pipe and V-Slot Screen

In the diagram on the left (cross section of slotted pipe), water must converge toward the slots. With the continuous-slot screen, water can move in a direct course.

A question that normally arises at this point concerns the reasons why the screen openings do not become clogged with the sand grains during development. Unless the openings of a screen are specially designed, they will clog badly during the development process and greatly limit the effectiveness of the screen. A sand grain cannot plug off a continuous slot because it can make contact only at two points, but it can lodge solidly in a round hole or square mesh. It is important that the slot openings widen abruptly toward the inside of the screen, because sand grains that pass the V-shaped slot will enter the screen without clogging and be removed during the development procedure; whereas sand grains are apt to become jammed in parallel-sided or inverted V-slots.

Another matter of great importance in the design of the well screen is the amount and distribution of the intake opening. Obviously, there must be a sufficient total area of intake opening, so that the velocity of the water as it enters the well screen will be low enough to avoid head losses that reduce the yield of the well. Of even greater importance, in most cases, is the proper distribution of the intake opening, in order for all portions of the aquifer around the screen to be effectively developed. This uniform distribution of slots will also be of prime importance if it should become necessary to treat a well for incrustation.

A slotted pipe with blank areas between the slots cannot produce uniform development, but a screen with a closely pitched, continuous V-slot can (Fig. 3). The screen slot openings must provide a direct, horizontal course for the surging action of the water during the development procedure, and there must be complete exposure of the aquifer around the well screen. Otherwise, effective development cannot be obtained. These are cardinal principles in well screen design.

The great effect that the nature of the sand and correct methods of development have on the yield of a well can be demonstrated by laboratory experiments. The graph of the particle size analysis of a fine sand, which has a permeability of 338 gpd/sq ft, is shown in Fig. 4—that is, 1 sq ft of the sand can transmit 338 gpd at 60°F with a 100 per cent hydraulic gradient. The effective grain size or 90 per cent retained size is 0.006 in. The coefficient of uniformity, which is a measure of the degree of sorting, the 40 per cent retained size (0.015 in.) divided by the 90 per cent retained size, is 2.5. Normally a screen slot opening of 0.014 in., which retains about half the formation, would be used. When that portion finer than 0.014 in. is removed, the permeability has increased to 1,530 gpd/sq ft, or 450 per cent of the original. Even in sand as fine and uniform as this, correct development produces very permeable material adjacent to the well screen. To the unaided eye, the change is so small that virtually no difference is apparent.

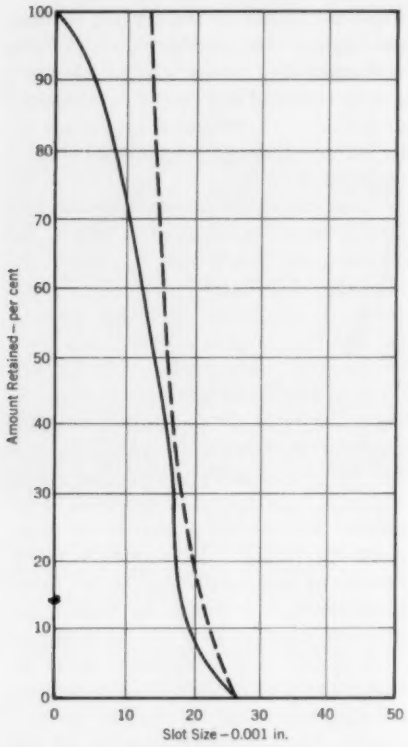

Fig. 4. Particle Size Analysis of Fine Sand

In the solid curve, effective grain size is 0.006 in.; coefficient of uniformity, 2.5; screen slot size, 0.014 in.; permeability, 338 gpd/sq ft. In the dashed curve (gravel envelope adjacent to screen), effective grain size is 0.014 in.; coefficient of uniformity, 1.2; permeability, 1,530 gpd/sq ft.

The analysis of a broad mixture of material ranging from fine sand to gravel is shown in Fig. 5. A cursory inspection of this material, because it is so much coarser, would lead most persons to believe that it is many times more permeable than the fine sand. Actually, the permeability is only 1,440 gpd/sq ft, or slightly more than four times as permeable as the fine sand. The permeability is relatively low because it is so poorly sorted; the coefficient of uniformity is 4.3. The wide range of particle size, however, is ideal for natural development. If a slot opening of 0.060 in. is used, the removal of the finer material would produce a filter adjacent to the well screen with a permeability of 46,500 gpd/sq ft. This is 1,340 per cent of the original permeability; thus, the yield of the well would be measurably increased.

Gravel Pack

In very fine and uniform sands it may be beneficial to place graded

coarse sand or fine gravel around the well screen to form artificially a filter between the screen and the formation sand. This requires a larger casing or bore hole in order to provide an annulus for the placement. Its beneficial effect on the yield of the well is principally because of the increased size of slot openings that can be used in the well screen. Also, a slight increase in yield comes from the larger effective diameter.

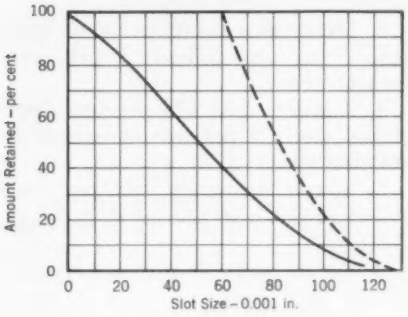

Fig. 5. Analysis of Mixture Ranging From Fine Sand to Gravel

In the solid curve, effective grain size is 0.014 in.; coefficient of uniformity, 4.3; screen slot size, 0.060 in.; permeability, 1,440 gpd/sq ft. In the dashed curve (gravel envelope adjacent to screen), effective grain size is 0.064 in.; coefficient of uniformity, 1.4; permeability, 46,500 gpd/sq ft.

The percentages of open area possible to fabricate in a well screen surface become less as the size of the screen slot opening becomes smaller. When this percentage is less than the porosity of the developed formation, there are likely to be measurable head losses at the screen. A practical dividing line is approximately 20 per cent porosity, which is reached on the best well screens having a slot opening of 0.025 in. Whether artificial gravel treatment should be used on fine uniform sand is a matter of economy, involving a choice between higher original costs and lesser pumping costs. The choice must be made on the basis of the conditions encountered in each instance.

Where artificial-gravel treatment is employed, definite procedures must be followed if the well is to be successful. First, a gravel must be selected that will stabilize the sand in the aquifer. After the correct gravel mixture is chosen, a screen must be selected with the correct size and distribution of slot openings to stabilize the gravel and facilitate the effective removal of the drilling mud and other fine material during development of the well. If the slot openings are too large and the gravel pack too coarse, sand will be pumped with the water, and the well may collapse.

Many wells constructed with slotted pipe, pump sand from the day they are completed. This occurs when the driller was unable to make a slot small enough to allow the use of a gravel pack that would stabilize the aquifer. It is difficult to predict the length of time before a sand-pumping well ends in collapse, with possible loss of a costly pump and pumphouse.

Dimensional Requirements

Questions that must frequently be considered by those responsible for preparing well specifications are: "What is the effect of diameter on the yield of a well? How much effect does the length of a well screen have?" If two wells are alike, except that one has twice the diameter of the other, the larger well yields only 11 per cent more water with the same drawdown. All other factors being equal, this is the

only increase that results from doubling the diameter. Obviously, in any case, the diameter must be large enough so that the velocity of the water entering the well is not excessive; usually the velocity should not be greater than 0.1 fps through the screen slots. Dimensional requirements for the highest pump efficiency are usually more of a governing factor in selecting diameter than is increase in yield.

Increasing the screen length in a given aquifer will usually improve the yield of a well appreciably more than doubling the diameter. For example, in a 50-ft artesian aquifer, under homogeneous conditions the yield from a screen 40 ft long would be 54 per cent greater than the yield from a screen 20 ft long.

Screen Metals

A final factor that requires scientific selection is the metal of the well screen. There is water in a few aquifers which can be classified as stable and benign for all practical purposes. Dissolved minerals are not deposited around the well, and the common metals, such as iron or steel, are not corroded; however, these aquifers are exceptions.

Treatment for incrustation consists of using acid or glassy phosphates to dissolve or sequester the deposition, or chlorine to destroy slime-producing nonpathogenic bacteria and to char the slime. Sometimes both chemicals are used in combination. Whichever chemical is used, the well screen must be made of a metal resistant to it. A qualified well driller with the proper equipment is required to assure good results.

Corrosion destroys a metal in what is basically an electrochemical process, the resistance of metals tending to be in the order of the galvanic series. If a screen is made of two metals, one will be sacrificial to the other, often plugging openings in the cathodic metal with products of corrosion. Metals used in well screens, in the order of their resistance to ground water corrosion, are:

1. Monel metal * (approximately 70 per cent nickel, 30 per cent copper)
2. Super-nickel metal (30 per cent nickel, 70 per cent copper)
3. Metal alloy † (96 per cent copper, 3 per cent silicon, 1 per cent manganese)
4. Stainless steel (74 per cent low-carbon steel, 18 per cent chromium, 8 per cent nickel) ‡
5. Silicon red brass (83 per cent copper, 1 per cent silicon, 16 per cent zinc)
6. Red brass § (85 per cent copper, 15 per cent zinc)
7. Common yellow brass (approximately 67 per cent copper, 33 per cent zinc)
8. Armco iron ||
9. Low-carbon steel.

Engineers generally agree that in the vast majority of wells either a high-grade silicon bronze, such as Everdur metal, or a Type 304 stainless steel should be used in the construction of well screens in permanent wells.

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* Manufactured by International Nickel Co., New York, N.Y.

† Known as Everdur metal; manufactured by American Brass Co., Waterbury, Conn.

‡ In some ground water, stainless steel is more corrosion resistant than Everdur metal.

§ Known as Anaconda red brass; a product of American Brass Co., Waterbury, Conn.

|| Manufactured by Armco Steel Corp., Middletown, Ohio.

Conclusion

The study of wells is far from complete. There is a rapidly growing demand for immediate answers to many of the water problems encountered, but their solution does not lie in haphazard guessing. More practical application must be made of the theory of ground water movement.

Ground water is a dynamic resource, and methods of obtaining it are constantly changing. Something new about well construction and ground water hydrology is learned almost every day. The greatest yield of ground water resources will come about from the cooperative efforts of contractors, manufacturers, and ground water scientists.

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AWWA M6
METER
MANUAL

Water Meters

Selection, Installation, Testing, and Maintenance

A manual on water meter selection, installation, testing, and maintenance has been prepared by Committee 8610 D—Meters for publication as one of the series of AWWA manuals on various aspects of water utility practice and procedure. The Manual will consist of the following chapters:

1. Early History of Water Measurement and the Development of Meters
2. Meter Manufacture in the United States
3. Kinds of Meters Commonly Used by Water Utilities
4. Meter Selection for Accurate Measurement of Various Customer Demands
5. Effects of Friction and Pressure Losses on Service Adequacy
6. Meter Installation
7. Periodic Testing of Meters
8. Test Procedures and Equipment
9. Maintenance and Repair of Positive-Displacement Meters
10. Layout and Equipment of Maintenance Shop
11. Meter Records

The first three chapters appear in this issue. The remaining chapters will be published in subsequent issues, following which the Manual will be made available as a separate reprint under one cover (price and publication date to be announced).

The information contained in this Manual is based upon the best known experience. The equipment and procedures described are believed to be applicable under normal conditions; their use in individual circumstances should be based on responsible judgment. Nothing in this Manual is intended to supersede, nor should it be regarded as superseding, the official AWWA standards on meters.

Acknowledgment is made to the following companies for their courtesy in furnishing illustrations for the Manual: Badger Meter Mfg. Co., Milwaukee, Wis.; B-I-F Industries, Inc., Providence, R.I.; Buffalo Meter Co., Buffalo, N.Y.; Calmet Meter Div., Worthington Corp., Fort Worth, Tex.; The Ford Meter Box Co., Wabash, Ind.; Gamon Meter Div., Worthington Corp., Newark, N.J.; Hersey Mfg. Co., Dedham, Mass.; Neptune Meter Co., New York; The Pitometer Assocs., New York; Rockwell Mfg. Co., Pittsburgh, Pa.; Simplex Valve & Meter Co., Lancaster, Pa.; Sparling Meter Co., El Monte, Calif. The use of a specific make of equipment for illustration in the Manual does not imply endorsement by AWWA, and it should not be inferred that equipment made by other manufacturers may not be equally suitable for the purpose described.

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Chapter 1—Early History of Water Measurement and the Development of Meters

THE measurement of flowing water as practiced today is usually given only passing thought. History records, however, the long span of time required to develop this science to the level now considered commonplace. A most interesting digest of information on the measurement of flowing water, written by the late Charles G. Richardson, has recently been published.* He so successfully assembled the data in approximate historical sequence that it is only fitting that excerpts from his work be used as the opening chapter of this manual:

A 1953 article in German, entitled "*Hundert Jahre Wassermessung,*" by engineer Martin Schaack of Karlsruhe, described in much detail the early attempts to measure water. Of interest are the following paragraphs:

> If one will take an extensive view of the progress of the technique of water meters, one will not overlook antiquity.
>
> A water meter which has been in operation for 3,000 years, in the Oases Gadames in North Africa, divides into equal parts the quantity of water served from the spring to the inhabitants of the farms. The procedure is as follows: A man pulls a pot of water on a cord from the spring ground. The pot has a hole, from which the water runs out again, a procedure which lasts 3 min. Each land proprietor gets water from the spring until the number of full pots . . . that the water commission allows him [is reached]. The man at the spring knows the irrigation program, and when the turn for the next land proprietor comes he throws a piece of straw in the drain. When the piece of straw arrives at the piece of land, which . . . should be irrigated, the owner opens a sluice gate that lets the water flow to his field and stops, by means of another sluice gate, the flow to the . . . irrigated plot of land. In this way a fair division is given to all.

Exhaustive research on the jurisdiction of ancient water supplies has given us a composite picture of this technique, before which we stand in admiration.

Babylon, a two-stream land, was the first of the ancient granaries that had an irrigation program. The water of the Euphrates and the Tigris led alternately from one stream to the other—that is, the water flowed in a standard difference, one time from the Tigris to the Euphrates and another time from the Euphrates to the Tigris, over and over again. It is not out of the question that the Tower of Babel, besides its well-known meaning as a temple, was also a signal station from which this water distribution was assessed. It was a technique which, in today's regulation of water supply of the Ruhr and in Holland, has a very similar parallel.

Chinese and Egyptian well builders have produced significant results (wells up to 500 m deep). The English were astonished, after having conquered the Indians, to find power catchments of 80,000,000-cu m capacity; dam length, 20 km; dam height, 6 m; which compare

* "The Measurement of Flowing Water," *Water and Sewage Works*, **102**:379 (1955).

favorably with dams of today. These arrangements were made, of course, without today's technical knowledge.

The water line from Mount Hagis Georgios through two valleys to the Castle Pergamon evidently was made of bronze, a costly material. This also appears to be the reason why not a single piece of this pipe has been found. Only the stones that served to anchor the ends of the pipelines remain.

Roman Adjutages

For nearly half a century, until 313 BC, the citizens of Rome were content to draw their water supply from the Tiber River, wells, and springs. As

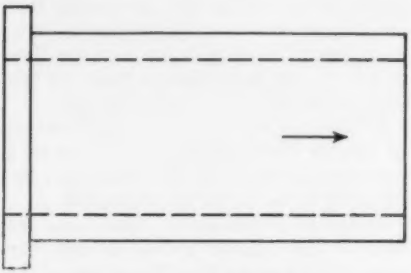

Fig. 1.1. Roman Adjutage

An adjutage was a simple bronze tube of a specific cross section.

in our own times, such sources became entirely inadequate to meet the needs of a rapidly growing city, and the first of the great aqueducts, the Appian, was constructed. This was followed, 40 years later, by the Anio Vetus and, during the next three centuries, by seven others.

All of them are described in meticulous detail by Water Commissioner Frontinus in his two books (now a collector's item) of *De Aquis Urbis Romae* (translated into English by Clemens Herschel under the title *The Water Supply of the City of Rome*).

One cannot pass by Frontinus with the mere mention of his name. The office of water commissioner (approximately 35 to 104 AD) was, from olden time, filled by the most distinguished citizens. Frontinus set an example for all future water commissioners to follow, in honest devotion to duty, thoroughness of accomplishment, and sterling character. His voluminous report can be read with profit and astonishment over the progress made during those ancient times in the development of metal pipe, pipe fittings, plug cocks, inverted siphons, ornate fountains and baths, and possibly in methods of measurement and filtration. Herschel interestingly comments:

> It must be remembered that we are speaking of the works of a very practical people. They were engineers by nature, rather than architects or men of science only; they taught the useful from choice, rather than that which was merely beautiful in design or tendency. They felt comparatively little predilection for "pursuing science for science's sake," as the phrase goes, while they pursued to the utmost of their abilities, and most ably for their day, that "art of directing the great sources of power in nature for the use and convenience of man," which constitutes the profession of the civil engineer.

After describing in great detail the construction of the nine huge aqueducts, Frontinus wrote:

> Having now given the builders and the age of each aqueduct, also their sources, lengths of channel, and order of heights, it seems to me not out of keeping to go more into detail, and to demonstrate how large is the quantity of water which is allotted to public and to private uses, as well as for luxury; and through how many tanks it is conveyed, and in what wards these are located; *how much water* is distributed within the city walls, how

much without, how much is used for water basins, how much for fountains, how much for public structures, how much on account of the state, how much by private consumers. But before I mention the names *quinaria, centenaria,* and those of the other adjutages [see Fig. 1.1] by which water is gaged, I deem it expedient to state what is their origin, what their discharge, capacity, or value, and what each name means; and to show, after presenting the rules according to which their proportions and capacity are computed, how I discovered their discrepancies, and the way I set about to correct them.

The adjutages to measure water are arranged either according to digits or inches. Digits are used down to the present day in Campania, and in very many places in Italy; inches in Apulia and elsewhere. The digit, according to common agreement, is the one sixteenth part of a foot, the inch the twelfth; but even as there is a difference between the inch and the digit, so also digits differ among themselves; some are called square, others round. The square digit is greater than the round digit by three fourteenths of itself; the round digit is smaller than the square digit by three elevenths, obviously because the corners are lopped off.

Just a few paragraphs further, we find the amazing statement:

But every adjutage is gaged either by its diameter or circumference, or by its area of clear cross section; from any of which its capacity may be found.

It seems natural that we turn to Herschel for pointed comment. He writes:

Let us see what ideas were extant on hydraulics in Frontinus' time. The most troublesome point of ignorance he had to contend with was a total inability to measure the velocity of water, or even to rightly and fully grasp the idea of such velocity, whether as flowing in an open channel or in closed pipes. He accordingly compares streams of water merely by the areas of their cross sections. A square foot of water is all one to him, whether it be one of the 8 sq ft of cross-sectional area of a stream in a conduit, or whether it be composed of the sum of 200 or more cross-sectional areas of lead pipes leading out of delivery tanks to fountains, or to water basins, or to private consumers, and ending and discharging at as many different elevations. To the expert of today, this seems excessively silly; and yet the same thing is constantly being done even now by those who ought to know better. The average man today will talk about "a stream of water that will fill a 6-in. pipe," a perfect parallel to the *quinaria* (0.907 English inch) of Frontinus; and there are hundreds of deeds on record conveying "square feet of water" for power purposes, just as though the law of falling bodies and its application to hydraulics had never been discovered; and unmindful of the fact, as one old Italian writer on water rights has expressed it, that to speak of a stream of water by its area of cross section is like estimating the volume of a cylinder merely from the area of its base.

Yet there is at least some evidence, as we read Frontinus, that he was frequently troubled over his adoption of pipe area as the sole measure of volume discharge, for he wrote, at one point in his history:

Let us not forget in this connection that every stream of water whenever it comes from a higher point and flows into a delivery tank through a short length of pipe, not only comes up to its measure, but yields, moreover, a surplus; but whenever it comes from a low point, that is, under a less[er] head, and is conducted a tolerably long distance it will actually shrink in measure by the resistance of its own conduit so that, on these accounts,

either an aid or a check is needed for the discharge.

In other words, a check of some sort was required *to make the pipe discharge the quantity normal for its size.* In another place, he writes:

. . . whence it appears that the amount measured by me is none too large; the explanation of this is that the more impetuous stream of water increases the supply, since it comes from a large and rapidly flowing river.

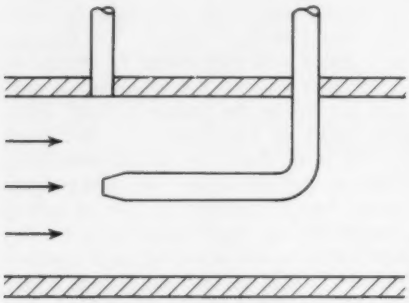

Fig. 1.2. Pitot Tube

The pitot tube measures the difference between static and flowing head. Through use of the relationship between flow rate and center-line velocity, a single central measurement can provide an approximate discharge figure.

Herschel comments:

And then he goes on again, worrying himself into all sorts of explanations why his gagings by areas, made irrespective of heads and velocities, do not balance. The frauds of the watermen, of the plumbers, and of others who draw water unlawfully always furnish a handy explanation, however.

Our perplexity increases when we realize that Hero, of Alexandria, thought by some to be the teacher of Frontinus, already had announced:

Observe always that it does not suffice to determine the section of flow, to know the quantity of water furnished by the spring. This we said was 12 square digits. It is necessary to find the velocity of its current, because the more rapid the flow, the more water the spring will furnish, and the slower it is, the less it will produce. For this reason, after having dug a reservoir under the stream, examine by means of a sundial how much water flows into it in an hour, and from that deduce the quantity of water furnished in a day. Thus one has no need to measure the section of the stream.

Notwithstanding the false premise of Frontinus, here indeed was the beginning of the art of measuring flowing water, which will be emphasized as we pass on to further developments in Roman practice.

Quoting Herschel:

But some control of the amount drawn had to exist, and we accordingly find that the measure of a grant in the city of Rome, A.D. 97, was the right to insert, at a designated place in the public delivery tanks, or cisterns, which received their supply, either directly or through lead pipes, from the public aqueducts, a circular bronze adjutage, or short piece of pipe, stamped by the public authority, not less than about nine inches long and of a designated diameter, some fifteen such diameters being in ordinary use; and to allow water naturally to flow through this adjutage; it being the law, moreover, to ensure a natural flow through the stamped bronze adjutage, that the lead or other pipe immediately downstream from it should have the same diameter as the adjutage, on a length of not less than 50 ft, measuring from the downstream end of the adjutage.

Frontinus definitely realized that there were other factors which limited the quantity of water which could be drawn. He says:

An adjutage placed at right angles and level, it maintains its proper measure; set against the current of the water and sloping down, it will consume more; set sloping to one side, so that the water flows by, and inclined with the current, that is, placed less favorably for swallowing water, it will receive the water slowly, and in a scant quantity.

It must also be left optional to attach any kind of lead pipe to the adjutages; but there must rather be attached for a length of 50 ft one of the same interior area as that which the adjutage has been certified to have, as has been ordinated by a vote of the Senate that "no one to whom a right to draw water from the public conduits has been granted shall have the right to use a larger pipe than a *quinaria* for a space of 50 ft from the delivery tank out of which he is to draw the water."

The water commissioner calls attention to frauds which were being practiced by attaching pipes of larger diameter to the adjutages and as a consequence, the water was not, he says, "held together for the lawful distance."

The Naples Museum exhibits three small bronze pipes which are believed to be genuine adjutages, 9 in. long and 0.72 in. in diameter. It was required that:

a. The adjutage must be entered at a designated point.

b. Water rights limited the quantity of water to be drawn and ended with the death of the grantee.

c. The setting of the orifices to be determined by the authorities.

d. Adjutages must be of a prescribed form, dimension, and material (bronze), and must bear the official stamp of the authorities.

Frontinus reports "cheating practices" discovered, in addition to the larger outlet pipe mentioned, as follows:

To some pipes no adjutages were attached. Such pipes are called uncontrolled, and are expanded or contracted as pleases the watermen.

When a water right is transferred to a new owner they will insert a new adjutage in the delivery tank; the old one they leave in the tank and draw water from it, which they sell.

He adds, significantly: "Most especially, therefore, as I believe, should the commissioner have in mind to stop this."

Pitot Tube

In 1730, Henri Pitot (1695–1771), distinguished French engineer, was using a vertical glass tube with a short 90-deg tip at the lower end pointing upstream, in the River Seine, to determine whether there was a relation between the rise of water in the tube and the velocity of flow [see Fig. 1.2]. Two years later, Pitot contributed a paper to *L'Academie Royale des Seines* describing his experiments and his tube, which he had combined with a second, static-head vertical tube.

It is significant that he discovered the height to which the water rose in his tube was proportional to the square of the stream velocity as, in that very year, John Bernouilli had published the fundamental relation of head to velocity squared of water flowing through pipes.

Important modifications were made in the pitot tube 125 years later by Darcy, another French engineer, improving the accuracy of the static-head readings and reducing the oscillations of the water columns.

Hiram F. Mills, of Boston, was the first American engineer to use the pitot tube (1875); John R. Freeman applied it to the measurement of fire-stream jets.

Many additional improvements in design have followed, including photographic reproduction of the head deflections. The device has proved a very valuable instrument, particularly in investigations to locate water wastage in the underground piping systems of towns and cities.

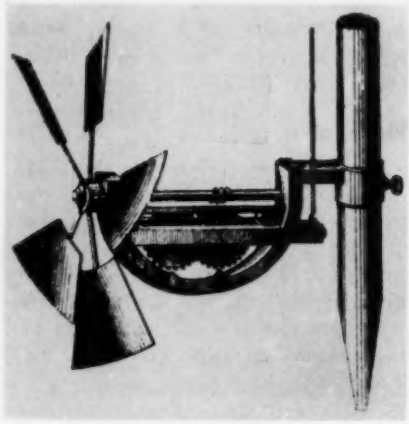

Fig. 1.3. Original Form of the Woltman Meter

In this form, the Woltman meter could measure flows only in an open stream. The revolutions of the water wheel were transmitted to a register by a gear train. For a stream of known cross section, the register could be calibrated to give accurate measurements of flow.

Orifice Meters

The so-called orifice meter is said to be one of the oldest devices for measuring or regulating the flow of fluids, dating back to the Romans of Caesar's time. Development of the thin-plate orifice, the most commonly employed type, did not begin, however, until the early days of the present century, and still continues.

The determination of the relation between flow rates and differential pressures for various designs [and] loss of head occasioned by the device installed in the pipeline . . . has been dependably established for various designs, and such data are quite readily available. Quoting from the ASME publication on *Fluid Meters,* 4th edition, the following statements are made as the characteristic of standard concentric thin-plate orifices:

> The pressure of the fluid drops abruptly as it flows through the orifice and, on the outlet side, the pressure continues to decrease slightly. The minimum value is reached at a short distance from the outlet side of the orifice. Beyond this minimum point, the pressure increases again slowly at first, then rapidly for a short distance, then again more slowly until its second maximum is reached several pipe diameters beyond the orifice plate. Since no guiding of the stream occurs on either the inlet or the outlet side of an orifice, the acceleration and deceleration of the fluid stream, which the pressure gradient manifests, is accompanied by considerable turbulence and consequent dissipation of energy (pressure), especially on the outlet side. Consequently, for the same diameter ratio, the downstream maximum pressure is much lower for an orifice than it is for a flow nozzle. In other words, the percentage of differential pressure recovered with an orifice is slightly less than with a nozzle and much less than with a venturi.

Orifice plates are largely employed in industrial plant pipelines, especially for the measurement of water and oils; municipally, for measurement of gas.

Current Meters

There was published in Hamburg, in 1790, by Benjamin Gottlob Hoffman, a booklet describing a form of

current meter, invented by Reinhard Woltman, for measuring flowing air and water. This seems to be the first practical meter for the purpose. It has since been materially changed in design and construction.

In general, it consisted of a very light water wheel, operated by the current, and carrying on its axis a worm for actuating wheels and a totalizer. The rate of flow was computed from the rotation during a given time period. Drawings show various forms of construction of the mechanism. Each size of meter had to be individually calibrated before use. The Woltman meter was illustrated [see Fig. 1.3] and described in a German handbook, *Die Hydraulik*, by G. Meilzner, published in Jena in 1878. At the time, it was not generally accepted that the Woltman meter could be used in a closed pipe.

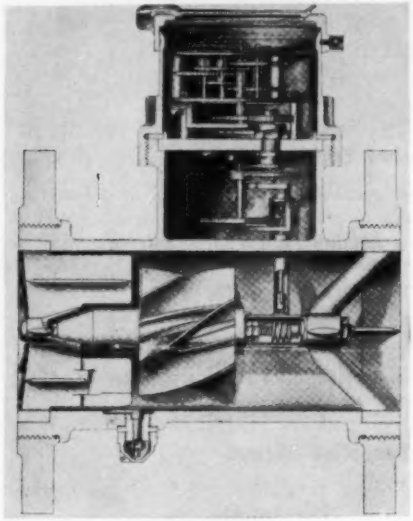

Fig. 1.4. Improved Form of the Woltman Meter

The use of a turbine wheel made possible the measurement of flows in a closed pipe.

The question of water measurement in its present form became acute when, for about 100 years, larger water works were being built in England to take care of increasing consumption. The first water meter was a reaction turbine counter with a cast-iron housing lined with bronze and other nonferrous metals. From 1852 on this type was supplied in great quantities and was serviceable for the situation at that time.

The first water meter was designed in England by a Mr. Siemens working with a Mr. Adams, in 1850. This was the reaction turbine type, which Siemens obtained permission to manufacture in Germany. The firm of Siemens & Halske began manufacture about 1865.

Although such meters were made and appeared to give fairly accurate results, the hydraulic laws governing their action were never fully determined and the designs were therefore empirical.

Considerable trouble was experienced due to corrosion, as the meter casings were of cast iron and the internal working parts of bronze.

[Quoting from Schaack]:

A decided step forward was made when, in 1865, the principal was reformed and, instead of the reaction turbine, an action turbine with a more durable runner was used. With this, the "wing wheel counter" of today was created in its basic form.

It lasted for a long time, until man had learned the cause of erosion. Friederich Lux discovered a new means, more through intuition than pure knowledge, in which he set the greatest part of the

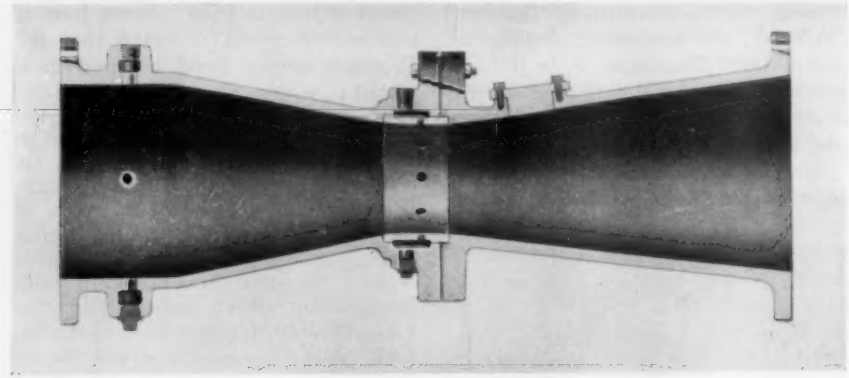

Fig. 1.5. Venturi Tube

The flow of fluid through a constriction in a pressure conduit results in a lowering of pressure at the constriction. The difference in pressure at the constriction and in the unconstricted portion of the conduit is a function of the flow rate and may be used to calculate the latter.

metal of the measuring works of his counter in hard rubber.

It was . . . Lux who first employed vulcanite for the meter mechanism. However, a good deal of difficulty was experienced at first, due to expansion of the material and to the quite unnecessary fear that the water would be contaminated by the sulfur used in vulcanization.

Improvements in vulcanite gradually were made and the material was accepted as being satisfactory in resisting corrosion.

All water meters for many years were made with vertical rotor spindles, which naturally necessitated the "bending" of flow lines through a double right angle. It was Woltman who designed a meter with a horizontal axle affording a through flow.

A 1910 ASME paper, entitled "River Discharge," refers to the earliest type of current meter as being practicable only for measuring surface velocity, but commenting: "About 1790, Woltman modified this wheel so that it could be used beneath the surface." [See Fig. 1.4.]

Propeller Meters

The propeller type of mechanical meter is relatively modern, designed for pipes and conduits much larger than standard domestic meters. Usually the complete meter forms a section of the pipe or conduit line and the propeller element is driven directly by the flowing water.

Care must be exercised to make certain that the stream approaches the propeller without agitation. This usually requires the insertion of a straightening-vane unit preceding the propeller.

Transmission of the velocity is made by direct or electric connection to a distant counter, or totalizer, to determine the volume of the water flow, which is read directly in gallons or cubic feet.

The Venturi Meter

A major contribution to the measurement of flowing water was the invention of the venturi meter [see Fig. 1.5] by Clemens Herschel in 1887. This achievement is fully described and illustrated in an article entitled "The 50th Year of a Great Invention," published in 1937.

As its original principles and design had developed, it was found that, for the first time, a simple primary unit having no moving parts, for direct installation in pipelines without limit to size, had thus become available. With small variation in calculable coefficient for a wide range of diameters, venturi meters are now in service in pipelines from $\frac{1}{2}$ in. to over 10 ft in diameter. The general proportions of design have been little altered since those determined by the inventor in his original calibrations.

The primary units, such as orifices and tubes, necessarily require secondary connecting indicators, recorders, and totalizers that are hydraulically, electrically, or pneumatically actuated. These have been developed in a great variety of design and principles of operation. . . .

Summary

The subject of water flow measurement, from a historical point of view, is an extremely lengthy one. It is an extraordinary fact that in our patent archives there were a larger number of patentable inventions for mechanisms for measuring water taken out between, say, 1870 and 1900, than for any other purpose. Most—in fact, all, save one here and there—died a natural death.

The sequence of progress was roughly as follows:

1. The rotary reaction turbine type
2. The rotary fan type with multijet inner casing
3. The reciprocating packed-piston volume types
4. The rotary semipositive meter, such as the cylindrical displacer, the elliptical displacer, and the nutating-disc type.

Chapter 2—Meter Manufacture in the United States

WHEREAS water meters manufactured in foreign countries have been principally of the velocity type, development in the United States was based on a different approach, which was to utilize a more positive means of water measurement. The history of water meter manufacture in the United States spans the past 100 years.

Early American Designs

Although patents for liquid meters were issued earlier, it is believed the first American water meter was one proposed by William Sewell, of Williamsburg, N.Y., in 1850. The first meter actually produced is claimed to be one made in 1857 by Henry R. Worthington of New York (Fig. 2.1). These early types of meters were of reciprocating-piston design and patterned after the familiar D slide valve used in steam engines. The original piston meter of Worthington consisted of two cylinders and plungers, with inlet and outlet ports so arranged that as water in one cylinder was discharged by the piston the other cylinder was filling. Water flow through such meters was subject to pulsations caused by the action of the pistons, and high friction losses were encountered.

In 1876, a patent was issued for a meter having two rotary pistons, and, about 1880, this was followed by a design of rotary meter having only one piston (Fig. 2.2). The now familiar design of the nutating-piston (or disc) meter was patented in 1887 and 1888 (Fig. 2.3).

Numerous difficulties were experienced with the earlier types of water meters, among which might be cited the limited quantities which the meters would deliver, very large friction losses, breakage of the pistons, and damage that occurred when the meter was frozen. The cast-iron frost bottom was not developed until later, being patented in 1896.

Along with improvements in design to increase capacity and lower meter friction losses, it soon became evident that, although meters of positive-displacement design had many advantages, other designs were necessary for measuring larger rates of flow and to reduce friction losses. Information available on velocity meters of foreign design undoubtedly influenced the production of velocity meters in larger meter sizes in the United States. The compound meter was developed to cover a wider range of flows than could be accurately measured by either of the other two basic types alone.

Concurrently with these developments, study was given to the necessity for a means of accurately measuring flow rates beyond the scope of velocity meters, such as pumping station outputs and very large industrial

flows. The late Clemens Herschel, while hydraulic engineer of the Holyoke (Mass.) Water Power Co., was plagued by the unmeasured use of water taken by large manufacturing concerns, including 25 large paper mills. Herschel gave his spare time to this problem for years. Finally, in 1886, he conceived the idea of a pressure differential tube which was appropriately named after Venturi, the Italian engineer who, 100 years before, had first concluded that a fluid under pressure, when passing through a converging pipe, gains velocity and loses head (pressure), whereas the reverse is true in a diverging pipe. Herschel's invention opened the field of water

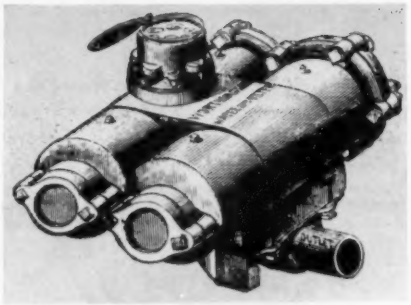

Fig. 2.1. Worthington Duplex Piston Meter

This was the first practical meter produced in the United States. Although it was invented more than 100 years ago, the principles of its operation are essentially those used in modern piston meters.

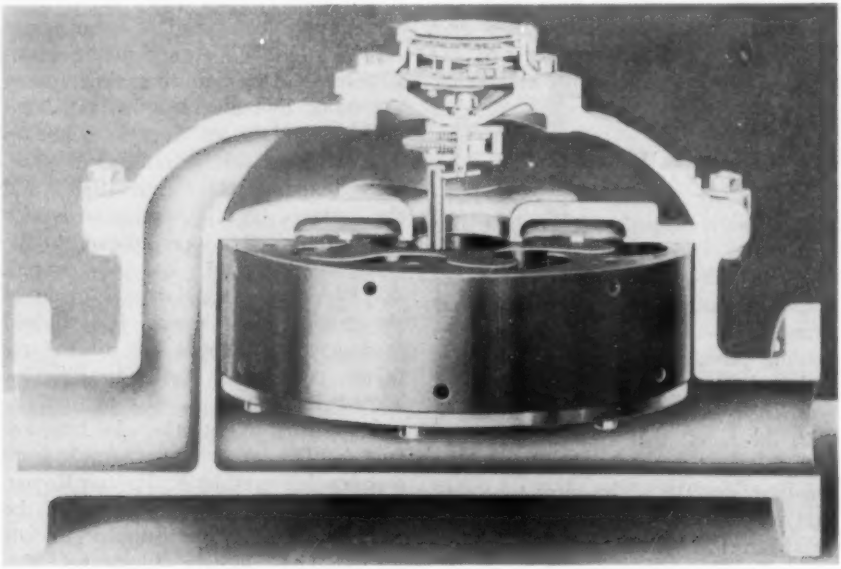

Fig. 2.2. Early Rotary-Piston Meter

This design of rotary-piston meter was patented in the 1880's. Although an improvement over the two-piston design, it was subject to high friction losses.

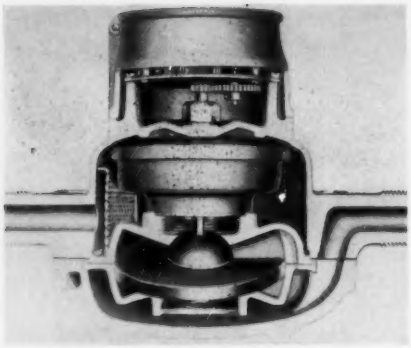

Fig. 2.3. Nutating-Disc Meter

This basic design, patented in 1887–88, is the most commonly used type of meter for ordinary domestic service in the United States.

measurement by the pressure differential method, which has been expanded to include orifice plates and various forms of converging and diverging tube sections as the measuring mediums.

Special-Purpose Meters

Meters for special purposes have also been developed, such as the fire line meter and the pitot tube. The fire line meter resulted from the demand of insurance underwriters that there be no restriction in pipelines serving private fire protection facilities and insistence by water utility operators that such services be metered, with the result that two types of special fire line meters were approved, the first in 1916. The pitot tube was first used in the United States in 1875 by Hiram F. Mills, of Boston, and later John R. Freeman applied it to the measurement of fire streams. Presently, this type of pitot tube is used primarily for fire hydrant flow measurements. A combined type of pitot tube for measuring flow in pipes under pressure was developed by Edward S. Cole in 1896 (Fig. 2.4). This type is the basis for leak surveys and measurement of flow and pipeline capacity.

In the early 1920's, oil-enclosed intermediate gear trains for water meters were developed. Prior to that time, all meters were equipped with open-wash, water-lubricated gear trains. The oil-enclosed gear train overcame a great deal of the difficulty with open type gear trains under corrosive water conditions and a majority of all meters now produced are so equipped.

Standardization

The first major effort in standardization of water meters was culminated in 1921 after many years of work by a committee composed of members of AWWA, NEWWA, and meter manufacturers. Prior to that time, many variations in meter lengths, rated capacities, and losses were in evidence. The work of this committee was reviewed again in the late 1930's and the current AWWA standards for cold-water meters were adopted in the early 1940's. A list of current AWWA meter standards is given at the end of this chapter. It is indeed fortunate that thought was given early to this problem of standardization, for a chaotic condition similar to that existing abroad might otherwise have resulted. The following paragraph, from a paper delivered by R. P. Van Royen, Amsterdam, at a 1937 meeting of the Association of Water Supply Officials in Holland, clearly illustrates this situation:

The great diversity which prevails in water meters with respect to construc-

tion, to overall length, and to connections (both as to bore and as to screw thread) is well known. The responsibility for this state of affairs lies as much on the maker as on the user. The former [not only] followed his own constructive design, which was excusable, inasmuch as he intended thereby to supply the best that could be had, but also his own particular details, as, for example, the screw thread. Once he had secured for himself the acceptance of his thread in any district, he bettered his chance of excluding his competitors from that district. But, on the other hand, makers were prepared to meet their customers' wishes by supplying other details than their own regular ones. Feeble attempts at standardization—for example, of overall length and of connections—only led to an increased diversity. In the German literature on the subject, I noted a statement that one firm makes 65 types of 3-cu m meters [3 cu m/hr = 13 gpm], which is due, among other things, to fifteen different overall lengths, between 130 and 220 mm; eleven different threaded ends of diameters from 23 to 38 mm; besides flange joints of ten different patterns. The number of boxes for meters up to and including 40 mm was no less than 185.

Further standardization of meters of American manufacture is desirable, and additional work is necessary to effect this, particularly for meter registers. The United States is so much better off in this respect than other countries, however, that the needed refinements should not be impossible to develop.

Competition is the lifeblood of the American system of free enterprise, and, of course, there is competition in the sale of water meters, just as there is in all other types of business. When it appears that the potentials for a profitable business are at hand, there are always individuals or groups with financial backing who enter the field, and this is as it should be. In the manufacture and sale of water meters, it appears that three rather distinct sales techniques have been followed in the past, particularly before 1920, when use of water meters was not widespread. Some firms developed a sound

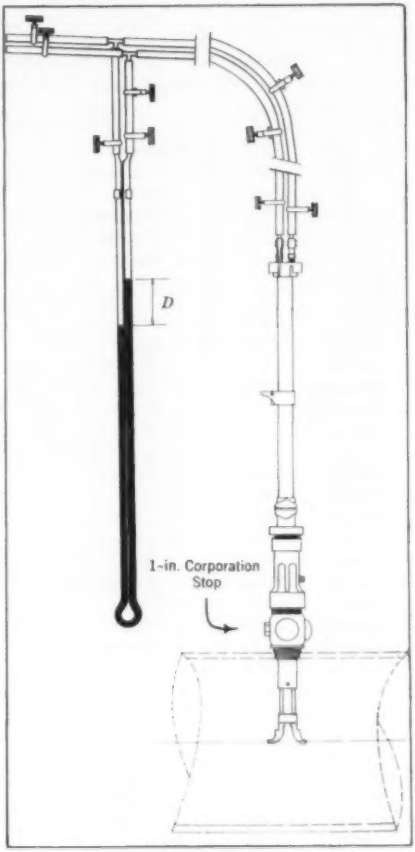

Fig. 2.4. Modified Pitot Tube

This form of the pitot tube, designed by Edward S. Cole in 1896, is used in leak surveys and for the measurement of flow and pipeline capacity.

basic design and adhered to it, incorporating improvements in the same design, and stressed interchangeability of parts. Others followed the principle of newer models and types, somewhat as is done in the automotive trade, whereas the third group copied a popular model or style and sold it at a lower price in a limited geographic area. As usually happens, the experience of the user ultimately dictates which product is the best from an economic viewpoint, and low first cost is not necessarily the determining factor, particularly with equipment as long-lived as a water meter. The mortality rate of firms

TABLE 2.1

Partial Listing of US Patents Granted on Meters and Metering Appurtenances

Patent No.	Year	Inventor	Description
425	1837	J. Bogardus	diaphragm meter
8741	1852	W. H. Lindsey	piston meter for boilers
9746	1853	J. Hartin	piston meter
11040	1871	L. F. Buschman	fluid meter
127907	1872	H. S. Maxim	liquid meter
161621	1875	H. S. Maxim	liquid meter
168354	1875	A. Swasey	water meter
168854	1875	D. C. Taylor	water meter
177733	1876	H. S. Maxim	liquid meter
229187	1880	R. J. Rogers	water meter
264375	1882	W. F. Travis	water meter
300630	1884	L. H. Nash	oscillating-piston meter
332935	1885	L. H. Nash	proportional meter
336146	1886	L. H. Nash	proportional meter
375023	1887	J. Thomson & F. Lambert	disc meter
379805	1888	L. H. Nash	nutating-piston meter
476104	1892	J. Thomson	proportional meter
485437	1892	J. Thomson	disc meter
520197	1894	J. Thomson	disc meter
602377	1898	J. Thomson	meter-protective device
742947	1903	C. C. Worthington	water meter
756431	1904	J. Thomson	water meter
785923	1905	J. A. Tilden	meter system
934504	1909	F. N. Connet	fluid meter
966316	1910	H. I. Dilts	water meter
971510	1910	J. A. Tilden	meter system
1001578	1911	J. N. Burton	water meter
1146674	1915	L. Van Gilder	oil-encased register
1244634	1917	E. H. Ford & A. Neff	electric remote-reading device
1492571	1924	W. L. Marden	oil-enclosed gear trains
1492572	1924	W. L. Marden	straight-reading counting wheel
1495010	1924	E. H. Ford	diaphragm couple between disc and register
1710563	1929	E. Allen	wiper for meter glass
1724272 1724873	1929	E. H. Ford	magnetic clutch for meter
1808209 1808210 1808211 1808212	1931	G. G. Earl	gulper for accurate measurement of small flows

engaged in water meter manufacture has been high. Since 1920 there have been fourteen independent firms manufacturing ordinary types of water meters for customer service, whereas in 1959 the number has been reduced by half. Spirited competition remains, however, and overall quality of product has been measurably improved over the years.

Patent History

To give some notion of the course of development of water meters in the United States, a partial listing of patents which have been issued for liquid meters is given in chronological order in Table 2.1. Apparent discrepancies exist between dates of manufacture and patent dates, because manufacture, in many cases, started when a patent was applied for, whereas the actual patent was not issued until several years later.

List of AWWA Standards

Listed below are the AWWA standards pertaining to cold-water meters, which were current in 1959. Because standards are subject to change, reference should always be made to the latest revision. An up-to-date list is available from the American Water Works Assn., 2 Park Avenue, New York 16, N.Y. Copies of individual standards may be purchased from AWWA at that address.

C700–46—AWWA Standard for Cold Water Meters—Displacement Type.
C701–47—AWWA Standard for Cold Water Meters—Current Type.
C702–47—AWWA Standard for Cold Water Meters—Compound Type.
C703–49—AWWA Standard for Cold Water Meters—Fire Service Type.
C704–50—AWWA Standard for Cold Water Meters—Current Type—Propeller Driven.
C705–57T—Tentative AWWA Standard for Testing Cold-Water Meters.

Chapter 3–Kinds of Meters Commonly Used by Water Utilities

PREVIOUS discussion has shown that three fundamental principles—volume displacement, velocity, and pressure differential—are utilized in the measurement of water flowing in conduits or pipes. Within each of these classifications various subclassifications are used to indicate more clearly the type of measuring medium employed. These subclassifications refer to the type of piston or disc movement or pressure differential producer employed.

Positive-Displacement Meters

Positive-displacement water meters are variously described as reciprocating-piston, rotary-piston, oscillating-piston, nutating-piston (or disc) meters. Of these, only oscillating- and nutating-piston (disc) meters (Fig. 3.1) have for many years been manufactured in this country for ordinary water utility service. They both operate on exactly the same principle except for motion of the piston. These meters have a separate measuring chamber into which the piston is fitted. Inlet and outlet ports are so arranged that water passes through the measuring chamber from the inlet to the outlet port. The piston (or disc) makes one complete cycle, thereby measuring the volume of water of the chamber assembly by physically and positively displacing it (measuring chamber volume is less that of the piston). Mounted above the measuring chamber is an intermediate gear train to convert the piston motion into convenient units of measure. Both the measuring chamber and intermediate gear train are mounted in an outer main casing which is designed for easy removal of the interior parts. Mounted on the upper portion of the main casing is the meter register. Connections between the intermediate gear train and meter register is made through a stuffing-box assembly and set of two gears, called meter change gears.

The following description is given to show how the displacement of water in the measuring chamber is transmitted to the meter register and converted to standard units of measure. Although the maximum speed of $\frac{5}{8}$-in. meters is limited to 435 piston revolutions or nutations per cubic foot by current (1958) AWWA standards, most meters have piston speeds considerably below this maximum. Furthermore, meters are manufactured with 3–5 gear-reduction trains. In the example that follows, a composite figure of piston speed of 310 nutations per cubic foot is used in combination with a four-gear reduction train.

The volume of the measuring chamber assembly of this composite meter is therefore approximately $\frac{1}{310}$ cu ft, and 310 revolutions of the disc spindle are required to cause the smallest hand of the meter register to make one complete revolution and record 1 cu ft.

The intermediate gear train consists of four sets of reduction pinions and

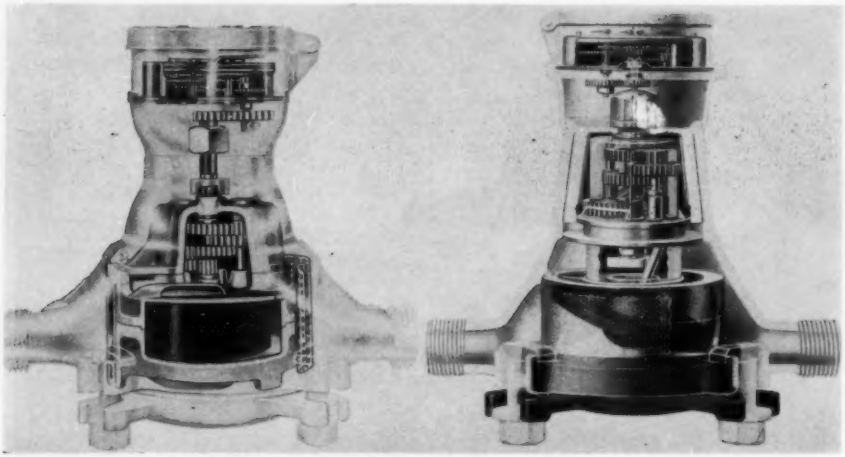

Fig. 3.1. Positive-Displacement Meters

The two types of positive-displacement meters shown above are the oscillating-piston meter (left) and the nutating-disc meter (right).

gears, each driving pinion having seven teeth and each driven gear having 28 teeth. The meter design (or trial) gears for registration in cubic feet would be a stuffing box gear having 24 teeth and a register gear having 29 teeth.

In any train of gears, the change in speed is the product of the number of teeth of the driver gears divided by the number of teeth of the driven gears. Therefore, in this meter, the reduction of the 310 revolutions of the disc spindle to 1 revolution of the 1-cu ft index of the register is done as follows:

$$310 \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{24}{29}$$

$$= \frac{7{,}440}{7{,}424} = 1 \text{ (approximately)}$$

This same meter geared for registration in gallons requires only a different set

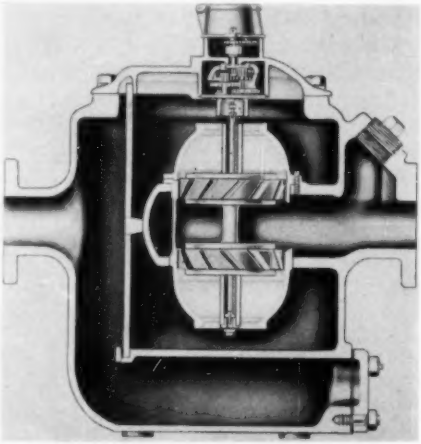

Fig. 3.2. Current Meter of Turbine Type

This is one of several types of velocity meters covered by AWWA C701. In this design, the rotation of a bladed wheel is transmitted by means of a gear train directly to the register.

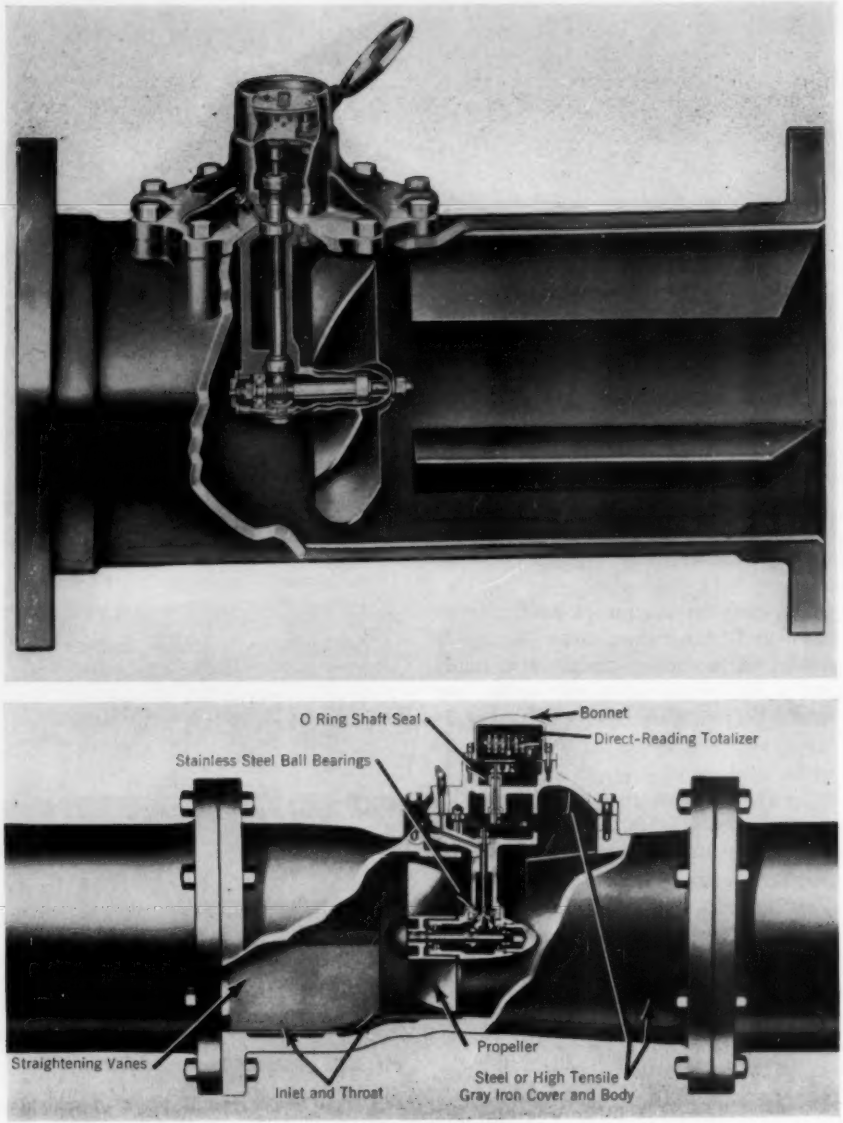

Fig. 3.3. Velocity Meters

The meters shown are of the type covered by AWWA C704

of change gears. For example, if a 24-tooth stuffing box gear and a 39-tooth register gear are used, and the number of revolutions of the disc spindle is increased from 310 to 413⅓, an increase of ⅓, as 10 gal is 1⅓ times 1 cu ft, then,

$$413\tfrac{1}{3} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{7}{28} \times \frac{24}{39}$$

$$= \frac{9{,}920}{9{,}984} = 1 \text{ (approximately).}$$

Thus, the smallest index of the meter register records 10 gal for each complete revolution.

These examples show that one basic design is utilized for meters recording in various units of measure by mere substitution of the change gears and register dial plate. Obviously, this feature has extreme value from a production cost standpoint but is not the only reason for change gears. These are also used to compensate for differences in meter accuracy resulting from manufacturing tolerances, wear, or other service conditions. This type of water meter is covered in AWWA C700.

Velocity Meters

Velocity meters are more commonly known as current meters. The design for customer service is covered by AWWA C701 (an example is shown in Fig. 3.2). Another design of velocity meter is covered by AWWA C704 for current type, propeller-driven cold-water meters (examples are shown in Fig. 3.3).

Some confusion exists because there are two separate standards for essentially the same type of meter; the reason for the two sets should be clarified. The original AWWA standard covered meters then (1923) being produced as general-service meters for customer use. The specifications for this type provide that: "The measuring chambers or cages for current type meters shall be made of bronze or nonferrous composition and shall be self-contained units firmly seated and easily detached and removed from the main case." The revised 1923 specifications are covered by AWWA C701 and are still retained for those current water meters commonly used for customer service installations. Coincident with the development and use of this type of current meter, other manufacturers produced a current meter which was designed for special purposes, such as pumping station output, where the more expensive venturi meter installation was not deemed warranted. Meters of this type do not comply with AWWA C701 in certain respects, principally in that they do not have a self-contained bronze or nonferrous measuring chamber or cage, but utilize either the main meter body or a section of the pipeline in which the unit is installed for this purpose. Because of increased use of these meters for special water utility applications, it was considered desirable to draft standards to cover them, and AWWA C704 was the result.

The principle of operation is the same for both types, in that the velocity of water passing through the impeller blading spacing causes the impeller to rotate in proportion to the flow velocity. This rotation is transmitted to the meter register by gearing similar to that described for displacement meters.

Compound Meters

Compound meters (Fig. 3.4), as used for customer service, are covered

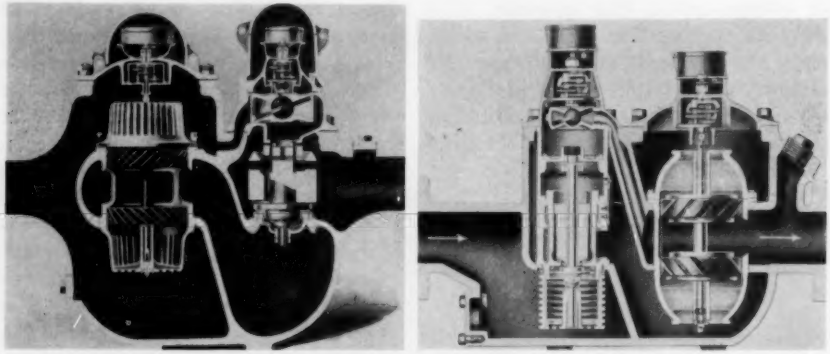

Fig. 3.4. Two Designs of Compound Meters

Compound meters, two examples of which are shown above, consist of velocity meter and a nutating-disc or piston meter, for measuring large and small flows, respectively. An automatic-valve arrangement diverts the flow into the appropriate compartment.

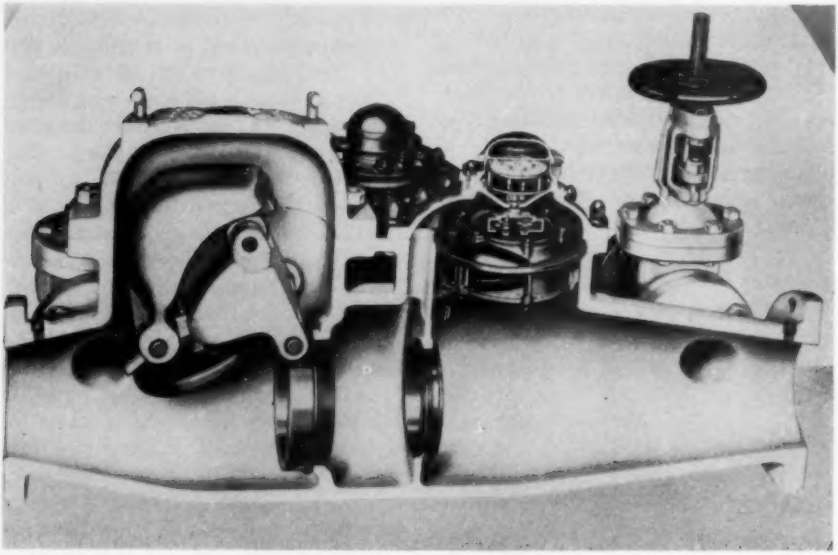

Fig. 3.5. Fire Line Meter

In this type of meter, only a portion of the total flow at high rates is diverted through the metering compartment. The latter is so geared as to record the total flow through the meter—that is, it measures proportionately.

by AWWA C702. Such meters are manufactured either in a single main casing or in two separate housings. In essence, the compound meter is two meters, one of the displacement type and the other of the current type, so designed that a valve arrangement diverts flow from one section to the other, depending on which meter is capable of more accurate registration. The current section of the meter obviously measures all rates of use within its design capacity for accurate measurement, but when water passes through the meter at low rates of flow the compounding valve closes and water is diverted through the smaller, disc section of the meter. This meter has the characteristics of both types, but imposes a higher friction loss at higher rates of flow than either disc or current meters, because of the added friction loss of the compounding valve.

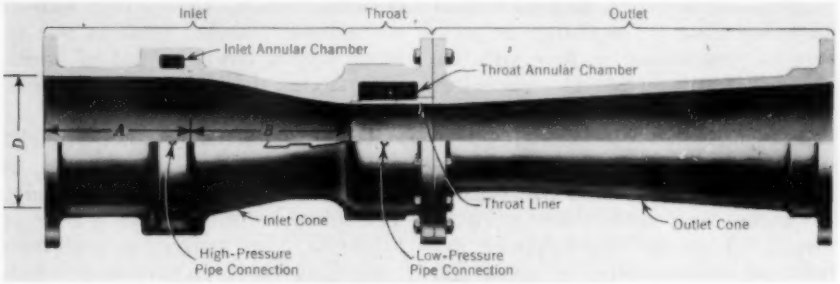

Fig. 3.6. Venturi Tube

The most advantageous feature of the venturi meter is that it has no moving parts in liquid flow, as it measures pressure differential by means of exterior pressure recorders.

Fire Line Meters

Fire line meters (Fig. 3.5), only two makes of which have been approved by the NBFU for use on fire lines, are known as proportional meters. They are similar to compound meters but, to meet certain requirements as to friction loss and free waterway, have been modified in several respects. The compounding valve, when open, provides a clear, unobstructed waterway through the meter. A portion of total flow is diverted from the main waterway through a meter, either of current or disc design, which is so geared as to record not only the water passing through it but also the larger quantity flowing through the main passage; hence, the term "proportional." When low rates of use occur, the main valve closes and water is bypassed through the small, meter section. This bypassing takes place through a separate passage and through a separate meter from that which records higher rates with the main valve open. These meters are not generally recommended for use on services other than those used exclusively for fire protection. These meters are covered by AWWA C703.

Pressure Differential Meters

Although the four types of meters thus far described are the ones water

meter departments use for general customer service and are therefore most concerned with, water utilities also use other types of water meters for special purposes and a general resume of their characteristics is in order. These meters are of pressure differential type and based on the principles propounded by Venturi. The actual measuring device is a restriction placed in a pipeline. The restriction causes a drop in pressure, with corresponding increase in velocity, when water is flowing through the line. This restriction is usually in the form of a converging and diverging tube section or an orifice plate. The change in pressure is proportional to flow and this change is converted to convenient units of measurement by a recording instrument.

Pressure differential meters cause smaller friction losses and are available in larger sizes than other types of meters. They are therefore used extensively for measuring pumping station output and other high flow rates.

Pressure differential meters consist of either two or three separate units: [1] a pressure differential producer (tube or orifice); [2] a recorder to measure the pressure differential; and [3] a transmitter unit, which is only necessary when the recorder is located some distance from the tube or orifice.

The following very brief description of a venturi meter is given to explain the principle of its operation:

A venturi meter tube forms a section of the pipeline. As flow proceeds through the inlet cone there is a rapid acceleration in velocity with a corresponding decrease in pressure, until the "throat" is reached. Here the velocity of the flowing fluid may be many times the velocity at the inlet. After passing the throat the flow enters the outlet cone where there is a gradual deceleration of flow and increase in pressure until full line size is reached at the outlet end of the tube.

The inlet section consists of the short cylinder *A* and the truncated cone *B* (Fig. 3.6). The inlet section usually contains a piezometer ring or annular chamber, sometimes referred to as the "annulus," which circumscribes the section. The fluid pressure enters the annular chamber through equally spaced vent holes drilled through the inner wall of the chamber. These vent holes are provided with bushings of bronze or other corrosion-resistant metal. The outside wall of the annular chamber contains one or more tapped holes, to one of which is connected the high-pressure pipe to the metering instrument.

The throat section follows the inlet section, and, as its name implies, is the most constricted part of the tube. The throat section contains a liner of bronze or other material as conditions require, the primary purpose of which is to prevent corrosion and encrustation at this critical area. This liner is carefully finished to specified diameter and profile, as accuracy of metering depends largely upon the shape, dimensions, and surface finish of this portion of the tube. The throat section usually contains an annular chamber which circumscribes the throat liner. Reamed holes through the liner admit fluid pressure to the annular chamber, while the outside wall of the annular chamber is tapped for the low-pressure pipe to the metering instrument.

The outlet section, made up of one or more castings, follows the throat section. It is essentially a long, truncated cone, the chief function of which is to reduce velocity and restore pressure during the flow from throat to outlet.

American Water Works Association

TENTATIVE

AWWA STANDARD

for

SODIUM ALUMINATE

This "Standard for Sodium Aluminate" is based on the best known experience and is intended for use under normal conditions. It is not designed for use under all conditions, and the advisability of use of the material herein described in any water treatment plant must be subjected to review by the chemist or engineer responsible for operations in the locality concerned.

Approved as "Tentative" Jan. 26, 1959

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AMERICAN WATER WORKS ASSOCIATION
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This "Standard for Sodium Aluminate" was prepared under the direction of James C. Vaughn for the Water Purification Division, AWWA. The standard was approved by the Executive Committee of the Water Purification Division and by the Water Works Practice Committee, and received the approval of the Association's Board of Directors on Jan. 26, 1959.

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Made in USA

Tentative AWWA Standard for

Sodium Aluminate

Part A—Material

Sec. 1A—Scope

This standard covers sodium aluminate for use in the treatment of municipal and industrial water supplies. It is intended for use with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

Sec. 2A—Definition

The sodium aluminate covered by this standard is a combination of sodium oxide (Na_2O) and aluminum oxide (Al_2O_3) with sufficient excess causticity to stabilize it. It is commercially available both in solution and in solid form. The solid form is a white or greenish-white powder containing 80–90 per cent $Na_2Al_2O_4$; the solution form is a concentrated solution containing approximately 32 per cent $Na_2Al_2O_4$.

NOTE: When ordering, the purchaser should state whether the material is to be in liquid or solid (pulverized or granular) form and stipulate the kind of packaging desired.

Sec. 3A—Sampling

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 4A—Methods of Testing

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

Sec. 5A—Impurities

The sodium aluminate supplied under this standard shall contain no soluble mineral or organic substances in quantities capable of producing injurious effects on the health of those who consume water that has been properly treated with sodium aluminate.

Sec. 6A—Rejection

6A.1. Notice of dissatisfaction with a shipment based on this standard must be in the hands of the consignor within 10 days after receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of notice of the complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples (Sec. 2B.2.4, 2B.3.2). In the event that the results obtained by the consignor do not agree with the results obtained by the consignee, the other sealed sample shall be for-

warded, unopened, to a laboratory agreed upon by both parties. The results of the referee analysis shall be accepted as final, and the cost of the referee analysis shall be paid by the party whose results show the greatest discrepancy from the referee analysis.

6A.2. On the basis of the retest or the referee test, the consignor shall remove the material from the premises of the consignee, or a price adjustment shall be agreed upon by the consignor and consignee.

Sec. 7A—Physical Requirements

7A.1. Solid sodium aluminate shall be dry, clean, and free from lumps and shall contain no foreign contaminating material in excess of the maximum set forth in this standard. The solid form shall be pulverized or granular, as specified.

7A.2. Liquid sodium aluminate shall contain no suspended material in excess of the maximum set forth in this standard and shall be sufficiently stable for prolonged storage.

Sec. 8A—Insoluble Matter

8A.1. Solid sodium aluminate shall contain no more than 10 per cent insoluble matter.

8A.2. Liquid sodium aluminate shall contain no more than 0.5 per cent insoluble matter.

Sec. 9A—Available Soluble Sodium Aluminate

9A.1. Solid sodium aluminate shall contain a minimum of 85 per cent available soluble $Na_2Al_2O_4$.

9A.2. Liquid sodium aluminate shall contain a minimum of 32 per cent available soluble $Na_2Al_2O_4$.

Sec. 10A—Excess Causticity

10A.1. Solid sodium aluminate shall have a causticity in excess of that required to combine with the Al_2O_3. The excess shall not exceed 5 per cent Na_2O.

10A.2. Liquid sodium aluminate shall have a causticity in excess of that required to combine with the Al_2O_3. The excess shall not exceed 7 per cent Na_2O.

Part B—Sampling, Inspection, Packing, and Marking

Sec. 1B—Scope

These procedures for the sampling, inspection, packing, weighing, and marking of sodium aluminate are intended for use with Part A (Material) and Part C (Testing Methods) of this document.

Sec. 2B—Sampling

2B.1. Samples shall be taken at the point of destination.

2B.2—*Solid sodium aluminate:*

2B.2.1. If the solid sodium aluminate is handled by conveyor or elevator, a mechanical sampling arrangement may be used.

2B.2.2. If the material is packaged, 5 per cent of the packages shall be sampled. No sample shall be taken from a broken package.

2B.2.3. Granular or pulverized sodium aluminate may be sampled by the use of a sampling tube at least $\frac{3}{4}$ in. in diameter.

2B.2.4. The gross sample shall weigh at least 10 lb and shall be mixed thoroughly and divided to provide three 1-lb samples. The samples shall be sealed in airtight, moistureproof, glass containers. Each sample shall be labeled to identify it and shall be signed by the sampler.

2B.3—*Liquid sodium aluminate:*

2B.3.1. At least 5 per cent of the containers shall be sampled. No sample shall be taken from a broken or opened container.

2B.3.2. The contents of each container to be sampled shall be mixed thoroughly by rolling or by other means, and a portion shall be taken from it of such size that the total gross sample shall consist of at least 10 qt. After thorough mixing of the gross sample, three ½-qt samples shall be sealed in airtight bottles. Each sample container shall be labeled to identify it and shall be signed by the sampler.

Sec. 3B—Packing and Shipping

3B.1. Solid sodium aluminate shall be shipped in nonreturnable steel drums of 250–325 lb, net, or in special moistureproof bags of 100–150 lb, net.

3B.2. Liquid sodium aluminate shall be shipped in steel drums or carboys.

3B.3. The net weight of the packages shall not deviate from the recorded weight by more than ±2.5 per cent. If exception is taken to the weight of the material received, it shall be based on a certified unit weight of not less than 10 per cent of the packages selected at random from the entire shipment.

Sec. 4B—Marking

Each shipment of material shall carry with it some means of identification. The net weight of the contents, the name of the manufacturer, and a brand name, if any, shall be marked legibly on each package.

Part C—Testing Methods

Sec. 1C—Scope

These methods for the examination of sodium aluminate are intended for use with Part A (Material) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 2C—Preparation of Tests

2C.1. Sampling shall be in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. *Solid sodium aluminate.* The sample delivered to the laboratory shall be quartered to approximately 100 g and this amount shall be reduced by mechanical grinding or by hand in a mortar to such size that all of it passes a No. 30 sieve. After thorough mixing, the sample shall be stored in an airtight container and weighed out rapidly to avoid change in moisture content.

2C.3. *Liquid sodium aluminate.* Liquid sodium aluminate shall be mixed thoroughly before a portion is withdrawn for examination, and the bottle shall be kept perfectly sealed after the sample has been removed.

2C.4. The laboratory examination of the sample shall be completed within 5 working days after receipt of sample.

Sec. 3C—Solid Sodium Aluminate

Methods of testing solid sodium aluminate for insoluble matter, available sodium aluminate, soluble silica, total soda, sodium carbonate, and excess sodium hydroxide are given below.

3C.1—Insoluble Matter

3C.1.1. *Reagent.* 1.0*N* sodium hydroxide solution.

3C.1.2. *Procedure.* Dissolve 5 g of the sample in a mixture of 80 ml 1.0*N* sodium hydroxide solution and 70 ml distilled water. Stir thoroughly

and boil gently for 15 min in a beaker covered with a watch glass. If necessary, add distilled water to replace volume lost. Filter through a quantitative filter paper (Whatman No. 42, or equivalent) and wash the sample four times with the same mixture used for the solution of the sample. Finally, wash the sample with hot water until it is free from caustic alkalinity. Dry the paper and residue in a crucible, ignite, and weigh. Save the filtrate for the determination of available sodium aluminate (3C.2) and soluble silica (3C.3).

3C.1.3—*Calculation:*

$$\frac{\text{Weight of insoluble residue} \times 100}{\text{Weight of sample}} = \text{per cent insoluble matter}$$

3C.2—Available Sodium Aluminate

3C.2.1—*Reagents:*

(a) Carbon dioxide gas (may be generated and suitably washed in the laboratory or obtained from a commercial cylinder)

(b) Phenolphthalein indicator.

3C.2.2. *Procedure.* Transfer the filtrate from Sec. 3C.1 to a 500-ml volumetric flask, cool to approximately room temperature, and make up to 500 ml with distilled water. Mix thoroughly, measure 50 ml into a 250-ml beaker, and add 75 ml hot distilled water. Place the beaker in a boiling-water bath and bubble carbon dioxide through the solution at the rate of 4 bubbles per second. Continue bubbling until precipitation is complete (approximately 30 min). When precipitation is thought to be complete, discontinue bubbling and allow the precipitate to settle. Remove some of the supernatant liquid and pass carbon dioxide through it. If no precipitate forms, the alumina has been precipitated completely. If preferred, the phenolphthalein indicator may be added to the solution before gassing begins, and the gassing may be continued for 20 min after the color of the indicator has disappeared. Filter with suction through two quantitative filter papers (Whatman No. 42, or equivalent) supported in a platinum cone. Wash thoroughly and carefully with hot distilled water. Dry the paper and residue in a platinum crucible and ignite at 1,000°C to constant weight (approximately 1 hr). Cool in a desiccator and weigh quickly to avoid the absorption of moisture. From the weight of alumina subtract the weight of soluble silica (3C.3) to obtain net weight of alumina. Save the filtrate for determination of total soda (3C.4).

3C.2.3—*Calculations:*

$$\text{Weight of } Al_2O_3 - \text{weight of soluble } SiO_2 = \text{net weight of } Al_2O_3$$

$$\frac{\text{Net weight of } Al_2O_3 \times 100}{\text{Weight of sample}} = \text{per cent } Al_2O_3$$

$$\text{per cent } Al_2O_3 \times 1.608 = \text{per cent } Na_2Al_2O_4 \text{ (sodium aluminate)}$$

3C.3—Soluble Silica

3C.3.1. *Reagents.* Concentrated hydrochloric acid.

3C.3.2. *Procedure.* Measure 50 ml of the filtrate from Sec. 3C.1 into a 250-ml beaker; acidify with concentrated hydrochloric acid, evaporate to dryness, and bake for 1 hr at 180°C. After the baked residue has been cooled, add 15 ml concentrated hydrochloric acid and 15 ml distilled water. Heat to boiling, filter through a quantitative filter paper (Whatman No. 42, or equivalent), and wash the residue with hot distilled water until free from chloride. Dry the residue and paper in a platinum crucible. Ignite to con-

stant weight. Cool in a desiccator and weigh.

3C.3.3—*Calculation:*

$$\frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100 = \text{per cent soluble } SiO_2$$

3C.4—Total Soda

3C.4.1—*Reagents:*

(a) 1.0*N* sulfuric acid

(b) 1.0*N* sodium hydroxide

(c) Phenolphthalein indicator.

3C.4.2. *Procedure.* Transfer the filtrate from the determination of available sodium aluminate (3C.2) to a 500-ml erlenmeyer flask. Add 25 ml 1.0*N* sulfuric acid and boil gently for 30 min to expel the carbon dioxide. Cool and titrate with 1.0*N* sodium hydroxide with phenolphthalein as indicator.

3C.4.3—*Calculations:*

$$8[\text{ml } H_2SO_4 - (8 + \text{ml NaOH})] = \text{per cent soda as NaOH (by volume)}$$

$$\text{per cent NaOH} \times 0.7748 = \text{per cent soda as } Na_2O$$

3C.5—Sodium Carbonate

3C.5.1. *Procedure.* Unless otherwise specified by the purchaser, the method to be used for the determination of sodium carbonate shall be to determine the carbon dioxide gravimetrically by the Underwood method, using 3 g of the original sample. The carbon dioxide is generated by the action of hydrochloric acid on the sample.*

3C.5.2—*Calculation:*

$$\text{per cent } CO_2 \times 2.409 = \text{per cent } Na_2CO_3$$

NOTE: The more rapid method of determining the loss of weight when a strong acid is used to decompose the carbonate is to use an alkalimeter. Although not as accurate as the Underwood method, it will normally be sufficiently accurate to determine whether or not the material meets the standard, and may be used at the purchaser's opinion. This apparatus is used only to determine the amount of sodium carbonate present. A 3-g portion of the original sample should be placed in the alkalimeter.†

3C.6—Excess Sodium Hydroxide

Obtain total sodium hydroxide as in Sec. 3C.4. Then:

$$\text{Total sodium hydroxide as NaOH} - (0.488\ Na_2Al_2O_4 + 0.755\ Na_2CO_3 + 1.33\ SiO_2) = \text{excess sodium hydroxide as NaOH}$$

$$\text{per cent excess NaOH} \times 0.7748 = \text{per cent excess NaOH as } Na_2O$$

Sec. 4C—Liquid Sodium Aluminate

Methods of testing liquid sodium aluminate for insoluble matter, available sodium aluminate, and excess sodium hydroxide are given below.

4C.1—Insoluble Matter

Weigh accurately 7 g of the sample solution in a weighing bottle and follow the procedure prescribed for the determination of insoluble matter in solid sodium aluminate (3C.1).

4C.2—Available Sodium Aluminate

4C.2.1—*Reagents:*

(a) Concentrated hydrochloric acid

(b) Concentrated ammonium hydroxide

(c) Methyl orange indicator

* UNDERWOOD, J. E. Apparatus for the Direct Determination of Carbon Dioxide. *Ind. Eng. Chem.*, **18**:1069 (1926).

† SCOTT, W. W. *Standard Methods of Chemical Analysis.* Van Nostrand, New York (4th ed., 1925). p. 237.

(d) Ammonium nitrate solution, 1 per cent.

4C.2.2. *Procedure.* Make the filtrate from Sec. 3C.1 up to 500 ml with distilled water. Transfer 25 ml of the solution to a 250-ml beaker and dilute to about 175 ml. Add approximately 7 ml concentrated hydrochloric acid and neutralize with ammonium hydroxide, using methyl orange as an indicator, and then add 0.3 ml in excess. Bring the solution to a boil, allow it to settle, and then filter through quantitative filter paper (Whatman No. 42 or equivalent). Wash with hot 1 per cent ammonium nitrate solution. Redissolve the precipitated aluminum hydroxide on the filter paper with 1:1 hydrochloric acid solution, and wash the precipitate off the paper alternately with this solution and hot ammonium nitrate. Wash into the original beaker, and repeat the precipitation as before. Wash thoroughly with hot ammonium nitrate solution and finally with hot water until the filtrate is free from chloride. Dry the filter paper and its contents in an oven at about 100°C, and burn off the paper slowly in a crucible. Finally, ignite over a blast lamp for 5 min, weigh quickly, and reignite to constant weight.

4C.2.3—*Calculation:*

$$\frac{\text{Weight of residue} \times 1.608 \times 100}{\text{Weight of sample}} = \text{per cent sodium aluminate}$$

4C.3—Excess Sodium Hydroxide

4C.3.1—*Reagents:*

(a) 0.02*N* sulfuric acid

(b) Phenolphthalein indicator.

4C.3.2. *Procedure.* Measure 25 ml of the solution from the 500-ml flask (4C.2) and place in a 250-ml erlenmeyer flask. Dilute to approximately 100 ml with distilled water, and titrate with 0.02*N* sulfuric acid with phenolphthalein as indicator.

4C.3.3—*Calculations:*

$$\frac{0.02N\ H_2SO_4\ (\text{ml}) \times 0.08}{\text{Weight of sample (g)}} = \text{per cent sodium hydroxide (NaOH)}$$

$$\text{per cent NaOH} - (\text{per cent } Na_2Al_2O_4 \times 0.488) = \text{per cent excess sodium hydroxide (NaOH)}$$

$$\text{per cent excess NaOH} \times 0.7748 = \text{per cent excess NaOH as } Na_2O$$

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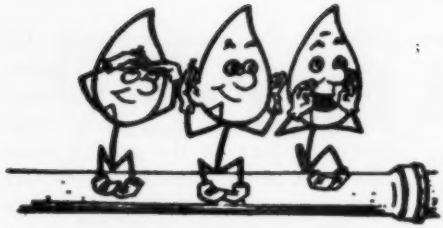


Percolation and Runoff

Come to SAN FRANCISCO, we still say, and with "San Francisco" coming closer, we hurry to remind you that the program (see P&R p. 64) is better than ever, the exhibit (more than 100 exhibitors, more than 200 booths) will be bigger than ever, the social events (four eveningfuls) will be more fun than ever, and the setting—WELL! But, as we intimated at some length last month and as Herb Caen has hinted in 278 pages of a book under that title, DON'T CALL IT FRISCO! *

In introducing his thesis, Herb's opus on the city he has in other books called Baghdad-by-the-Bay, is characteristically expostulatory in its caliginosity:

Don't call it Frisco—it's SAN Francisco, because it was named after St. Francis of Assisi. And because "Frisco" is a nickname that reminds the city uncomfortably of the early, brawling, boisterous days of the Barbary Coast and the cribs and sailors who were shanghaied. And because "Frisco" shows disrespect for a city that is now big and proper and respectable. And because only tourists call it "Frisco," anyway, and you don't want to be taken for a tourist, do you?

So don't call it Frisco—even though there's a big bar on Sixth Street that is called The Frisco in neon letters ten feet high. That's just one of those things that sneak by now and then when a city doesn't pay attention. One of these days a Vigilance Committee will come along and tear down that sign, letter by letter, and string up the offending proprietor from the nearest lamppost.

Because you don't call it Frisco. Not right out loud, anyway.

Oh—and one more thing.

Don't call it Frisco. Don't ask me why. Just don't.

But DO COME Jul. 12–17!

Eviscerated was the advertising of the "Evis Water Conditioner" last month when the Federal Trade Commission ordered a stop to claims that it has any beneficial effect on water. Eviscerated, too, was our hope that scientific miracles might mysteriously be benefiting water, as the hearing examiner had intimated when, in an earlier stage of the action, he dismissed the case on the grounds that expert witnesses had not proved that it was impossible for the Evis device to affect water beneficially. Not only did the commission's final decision remove this hope, it disintegrated it (see text p.

* Doubleday & Co., Garden City, N.Y. (1953).

(Continued on page 56 P&R)

(*Continued from page 55 P&R*)

708, this issue), letting us down once more with the inescapable conclusion that miracles will ever cease.

Ceaseless, perhaps—if not completely de-ceased by frequent scientific evisceration—remains that also overly unexplained "miracle"—dowsing. Such, certainly, seems to have been the conclusion of two Harvard psychologists whose nationwide survey of the subject led them to report, in the *GeoTimes,* that, recognizing "there is no evidence meeting scientific standards that would convince us that water witching works," they nevertheless felt:

> Water witching will persist in this country as long as individuals must choose well sites under conditions where they have few external guides as to which of several possible sites will minimize their chances of paying heavily for the water they need.

And in persisting, dowsing seems to remain both unchanged and changing —unchanged, that is, in the faith of its followers and its appeal as publication copy, while changing to suit its technique and rationale to modern ways and words.

Tom Anderson, of Norwood, Ohio, is an example of the rhabdomantic modern, having lately adopted a plastic Y with a small vial of water clipped to its tip for his explorations. Of all the twig materials—peach, hazel, wire, and whatnot—that he has used in more than 40 years of divining, Tom claims plastic is best because it cannot be affected by another underground substance. And "best" for Tom is pretty good, as he can't remember ever bringing in a dry well, regardless of the wand. An old stick in the hand, meanwhile, is Prudential Insurance Co. Agent Nelson T. Smith of Washington, N.J., who has exercised his unexplained powers strictly for friends strictly for free for the past 25 years. Like most of the 25,000 dowsers now active in the US, Nelson can determine the depth at which the water he divines is to be found, his technique involving backing away 3 ft from the indicated well site, stopping there to count the number of quick dips the twig will make, and multiplying this number by three to obtain the depth, in feet. Other dowsers elsewhere, using everything from monel metal strips to corset stays and turkey wishbones, determine not only location, but quantity and quality of water as well.

Meanwhile, only the fear of revealing atomic secrets, we understand, prevents disclosure of what *really* makes dowsing work, and we must be content with such engineering expositions as that presented by Kenith W. Templin, senior electrical engineer for the Byron Jackson Div. of Borg-Warner Corp., before the Engineers & Architects Institute of Los Angeles:

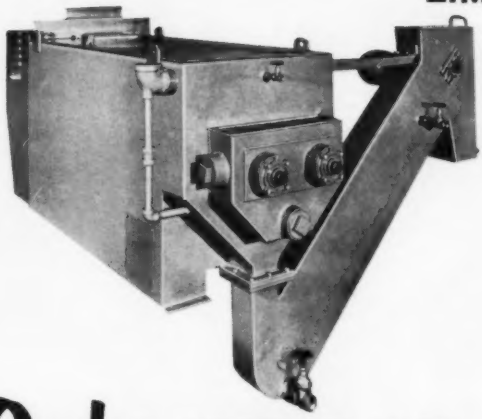
> An underground flowing stream of water will cause an imperceptible muscular contraction in the dowser's arms and this, in turn, will cause the stick to move. The reason the forked stick acts as it does is simply because, in the method of holding, the two arms of the Y are bent out severely. This effectively makes a toggle mechanism out of the stick, and the slightest movement of the wrists (unnoticed by the dowser himself) will trip the toggle and all the energy which was originally put into the system is now released in bending the straight end of the Y down. In so doing it will twist the bark off, etc. The method I have investigated *utilizes*

(*Continued on page 58 P&R*)

Specify

VISCOMATIC®

LIME SLAKERS!



CUT SLAKING TIME

SAVE ON LIME

Only INFILCO

has the experience gained from the manufacture and installation of many automatic torque controlled constant viscosity lime slakers.

PROVED IN PERFORMANCE

The "VISCOMATIC" Slaker slakes lime as a paste with true pug mill action...slakes fast with cold water...provides maximum hydrate availability.

Torque actuated water controller maintains constant viscosity ...assures proper slaking with little attention...eliminates temperature controls, water metering and insulation.

Write for INFILCO Bulletin 255. It describes the "VISCOMATIC" Lime Slaker and its utilization in water, waste, and process applications.

G91

INFILCO

INFILCO INC.

General Offices—Tucson, Arizona

Field offices throughout the United States and other countries.

(*Continued from page 56 P&R*)

the wire from two coat hangers and I have been amazed to find that it will work for 95 per cent of the people who try it.

The only thing we don't understand is where does he hang his coat?

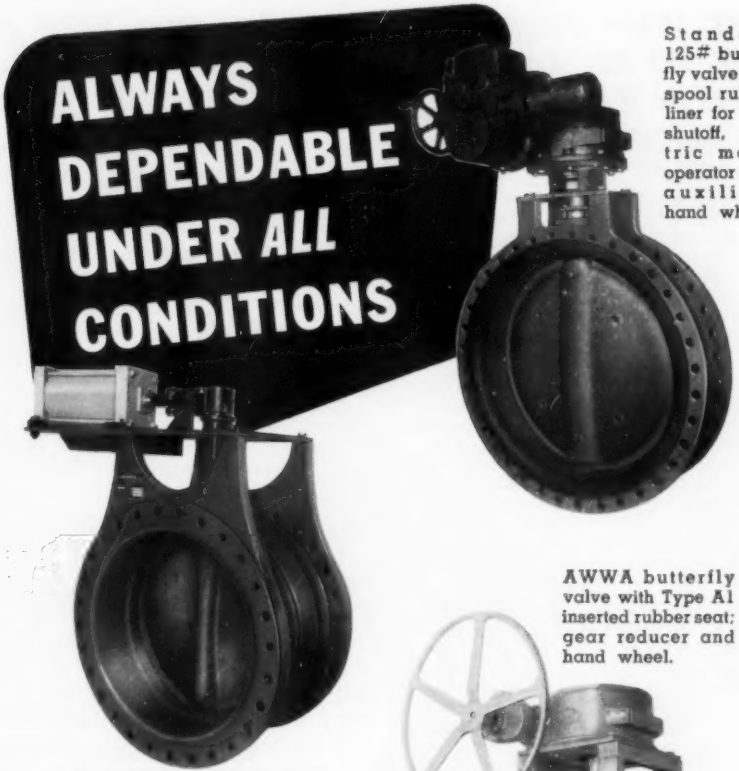
In memory of Frederick Ohrt, the new Honolulu Public Service Building (see cut) bears a plaque on which appear his likeness and the words: "Dedicated as a tribute to and as another fulfillment of his vision and leadership in developing Honolulu's outstanding water system." Ohrt, who died a year before the completion of the building, was manager and chief engineer of the city's Board of Water Supply for 27 years.

To H with the H-bomb is certainly the current attitude of the public generally. It isn't that people are not aware of the potency of fusion, fission, and fallout—even the news of increased cancer hazards and certain genetic damage from distant bomb tests are alarming enough. It isn't that people don't know how to prepare for the emergency—or, at least, how to learn how. It probably is because they will always remain convinced that it can't happen here.

How many of your friends have prepared shelter areas in which they and their families can remain for 2 weeks fully supplied with water, food, battery-operated radios, first-aid kits, blankets and bedding, a stove for heat and cooking, and containers for both garbage and human waste? Have you? Or, having convinced yourself that it can happen here and having read OCDM bulletins L-2-18—Facts About Fallout

(*Continued on page 60 P&R*)

ALWAYS DEPENDABLE UNDER *ALL* CONDITIONS



Standard 125# butterfly valve with spool rubber liner for tight shutoff, electric motor operator and auxiliary hand wheel.

AWWA butterfly valve with spool rubber liner for tight shutoff; air cylinder operator.

AWWA butterfly valve with Type A1 inserted rubber seat; gear reducer and hand wheel.

Rockwell valves for water control and shutoff service assure the MOST in reliability: minimum restriction to flow; minimum pressure drop; less installation space and maintenance. Bulletins 581 and 582 tell why.

ROCKWELL SINCE 1888 BUILT

BUTTERFLY VALVES

W. S. ROCKWELL COMPANY

2609 Eliot Street, Fairfield, Conn.

CAST IRON PRESSURE PIPE TO BE MADE BY GRIFFIN WHEEL CO.

Select Council Bluffs, Iowa, Site

COUNCIL BLUFFS. Cast iron pressure pipe will be made by Griffin Wheel Company at its Council Bluffs plant, it was announced by Goff Smith, President. Mr. Smith also announced the formation of the GRIFFIN PIPE DIVISION, to manufacture and market pipe products.

Target 1960 Market

Production facilities will be completed in a few months, and first deliveries of pipe are scheduled for March, 1960. Modern, automated machines will produce pipe by the Delavaud process of centrifugally casting metal in permanent, water-cooled molds, in 4- to 12-inch diameter sizes.

Modern 20-Ft. Lengths

To reduce labor costs in installing pipe, Griffin machines are designed to manufacture pipe in 20-foot lengths, as opposed to conventional 16- and 18-foot lengths. Pipe joints will include slip-on, mechanical joint, and bell and plain end, and will be made in accordance with American Standards Association, American Water Works Association, and Federal Specifications for water and gas distribution.

New Research Center

Facilities for pipe research and the development of new pipe products will be included in Griffin's new research center, under construction in Bensenville, Illinois. In addition to basic research, activities will center around metallurgical, chemical, and ceramic problems, and the improvement of quality control techniques.

American Steel Foundries Subsidiary

Founded in 1877, Griffin operates 6 iron and 5 steel foundries producing car wheels for the railroad industry, and a brass foundry. The company also produces specialty ferrous castings, including centrifugal castings of iron and combination iron and steel. Griffin is a subsidiary of American Steel Foundries, which has 26 plants in 15 states and Canada.

(Continued from page 58 P&R)

Protection, H-11-1—Emergency Sanitation at Home, and MP-2-1—Home Protection Exercises,* would you?

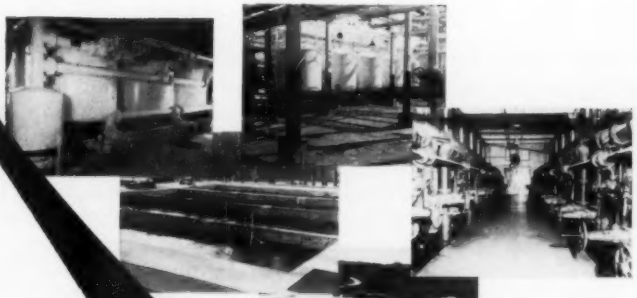
And if not for yourself, for your community has your utility a disaster plan worked out and ready to function in *any* kind of emergency? Have you studied OCDM bulletins TB-11-16—Minimum Potable Water Supply Requirements in Civil Defense Emergencies and TM-13-2—Operation and Repair of Water Facilities in Civil Defense Emergencies? *

It shouldn't happen, of course, but should it, wouldn't the "To H" be with family and community?

Back to the sea is the way we seem to be headed these days, not just for water supplies, but for military mastery, for food, for weather control, for mineral wealth, and for clues to the origin of man, as well as his continued well-being. The current story of fresh water from the sea is an active one, with not only the federal government, but many private organizations pushing ahead fast in the search for the most practical and economical means of making the sea around us fit for inside us (see April P&R, p. 38). Meanwhile the Committee on Oceanography of the National Academy of Sciences–National Research Council has urged the doubling of our deep-sea research during the next 10 years: to discover how best to conduct and combat submarine warfare; to assess the oceans' fish resources and determine

* Available from Superintendent of Documents, US Government Printing Office, Washington 25, D.C., at the following prices: L-2-18, 10 cents; H-11-1, 15 cents; MP-2-1, 15 cents; TB-11-16, 5 cents; TM-13-2, 25 cents.

(Continued on page 62 P&R)



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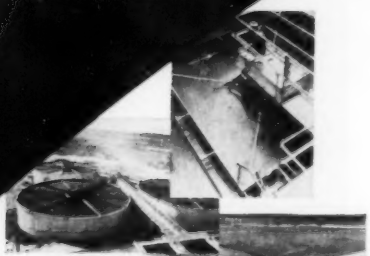
A *Complete* Line of Water Treatment Equipment

High-Rate Softeners and Clarifiers
Sedimentation and Settling Basins
Flocculators • Filters
Zeolite Softeners • Coagulators
Iron Removal Systems • Flash Mixers
Aerators • Chemical Feeders



WRITE FOR GENERAL BULLETIN
WC-117 AND SPECIFIC BULLETINS

GRAVER

Municipal Dept: M-412-A

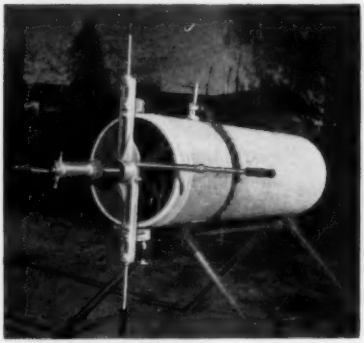
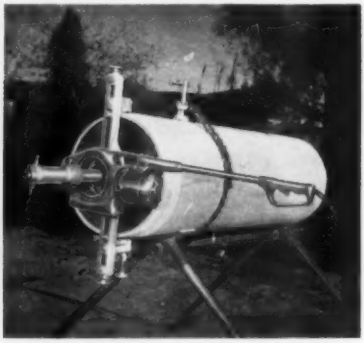
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.

(Continued from page 60 P&R)

means of increasing them by breeding and feeding techniques; to explore the relationship of the ocean-air interchange and the mixing of warm and cold ocean currents as a means of determining and, eventually, controlling weather; to reap the manganese-rich nodules that cover large areas of the ocean floor, as well as to investigate means of exploiting other mineral riches of the bottom of the sea; and, in the process of all these investigations, which are expected to plumb even the 7-mi depth of the Marianas Trench, to push back the horizon still further on the first forms of life on Earth. It is perhaps our marine origin that has sent the medical world, too, back to sea for remedies. Thus, not many years ago, it found that salt water provided the best medicine for those who had sustained severe burns. And no more than a month ago Soviet scientists announced that the injection of sea water in a ten-treatment series had been found to correct acute myopia, eyesight improving after the very first injection.

In this last discovery, much more than in the prodigious possibilities of all the others, we see hope for the world, for it is certainly acute myopia that permits both East and West to waste their energies and resources on weapons which, if used by either, will make the sea not only the source but the sole habitat of any life that survives —250,000,000,000 years back to the sea.

(Continued on page 108 P&R)

PILOT FIELD LATHES save money by machining asbestos-cement pipe right on the job!

Make factory-like ends on any length when and where you need them. No waiting – no delays.

Power or manually operated. All sizes from 4" thru 20".

Write for details and name of nearest distributor.

Distributor inquiries invited

PILOT MANUFACTURING COMPANY

P.O. BOX 2127, TORRANCE, CALIFORNIA

1915 photo of coal-tar enameled water line installation—still in service in Baltimore's system.

"Wherever Water Flows STEEL PIPES IT BEST"

STEEL PIPE LASTS!

Coal-tar enamel lined and coated steel pipe resists deterioration best

Steel pipe offers many advantages for water lines: ductility, strength, long lengths, and *long-life.*

Spun coal-tar enamel linings and exterior coatings assure long term economic operation of strong steel pipe. Spun coal-tar enamel lined steel pipe has the smoothest internal surface, and the highest flow capacity, of any type of water pipe. And this high flow capacity is retained over the life of the line, because coal-tar enamel prevents tuberculation and incrustation.

The outside coating of coal-tar enamel and the wrap protect the exterior of the tough steel pipe, insuring long service from steel water lines.

Steel pipe lined and coated with coal-tar enamel is truly your best investment in water pipe.

STEEL PLATE FABRICATORS ASSOCIATION

105 West Madison Street, Chicago 2, Ill.

STEEL PLATE FABRICATORS ASSOCIATION

San Francisco Technical Program

MONDAY MORNING, Jul. 13

Water Utility Management Development Session

Address of Welcome.....*Mayor* G. Christopher
Upgrading the Water Supply Industry.....Lewis S. Finch
The Business and Defense Services Administration.....Horace B. McCoy
AWWA's Water Utility Advancement Program.....*Led by* James B. Corey
Good Utility Citizenship—What It Can Mean.....M. M. Jorgensen
Count Down to Oblivion.....Robert Gros
Interest of the National Junior Chamber of Commerce in Water Resources....Robert Cox

Water Purification Division

Radioactivity of Surface Waters of the US.....L. R. Setter
Discussion.....H. H. Gerstein, Harry P. Kramer, Harold E. Pearson & James C. Vaughn
Water Analysis by Neutron Activation.....
Harry P. Kramer, R. L. Blanchard, G. W. Ledicotte & D. W. Moeller
Stabilization of Magnesium Hydroxide by Upflow Clarifiers.....T. E. Larson
Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction.....
H. O. Hartung & J. L. Tuepker

MONDAY AFTERNOON, Jul. 13

Water Resources and Water Utility Management Divisions—Joint Session

Development of the Upper Colorado River.....Ernest O. Larson
The Philosophy of a Model Water Law.....Arthur M. Piper
East Bay's New Aqueduct.....James W. Trahern
Water Well Stimulation—A Survey of Current Practices.....Louis Koenig
Application of Hexadecanol to a Municipal Water Storage Reservoir.....
Morrison B. Cunningham, J. K. G. Silvey & Walter U. Garstka

Water Distribution and Water Purification Divisions—Joint Session

Principles of Coagulation.....A. P. Black
Conversion of Saline Water.....Everett D. Howe
Discussion.....Sheppard T. Powell, Louis Koenig & Vivian F. Estcourt
New Delhi Hepatitis Epidemic.....Joseph M. Dennis
Discussion.....Abel Wolman & Norman Clarke or Richard Woodward
Cross-Connection Control—Panel Discussion.....*Led by* Andrew Dempster,
E. Jerry Allen, Henry J. Ongerth & Ray L. Derby

TUESDAY MORNING, Jul. 14

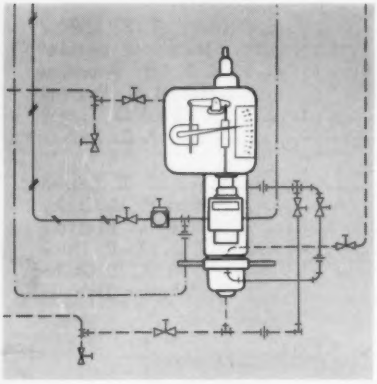
Water Resources Division—General Session

California's Battle for Water.....Lauren W. Grayson
Progress of the California Water Plan.....M. J. Shelton
Water—America's Number One Problem.....Fred A. Seaton
New Jersey's Forward Step in Water Supply.....William J. Orchard
San Francisco's Water Supply.....James H. Turner

(*Continued on page 66 P&R*)

FLUIDICS

is a Pfaudler Permutit program providing a modern, imaginative approach — plus the specialized materials and equipment — for handling and processing and controlling more profitably the liquids and gases which are the lifeblood of our manufacturing economy.



FLUIDICS AT WORK

New pneumatic transmission system more accurate, more dependable

The diagram shows a typical setup for the new Simplex system for transmitting rate of flow and loss of head to a receiver.

Rate of Flow

The new Type PN transmitter combines the exceptional accuracy and range of a differential converter operated by a mercury float with the traditional dependability of pneumatic transmission.

The transmitter consists of a differential converter which extracts the square root flow function from a primary and then positions a pneumatic motion transmitter. The transmitter produces a pneumatic 3 to 15 psig linear signal. A booster pitot diaphragm in the motion transmitter insures a low lag coefficient and fast transmission.

Besides getting a linear signal without using supplementary pneumatic relays, this new unit gives you point accuracy over wide ranges of flow with minimum differentials. The booster permits accurate transmission over long distances with minimum lag.

Loss of Head

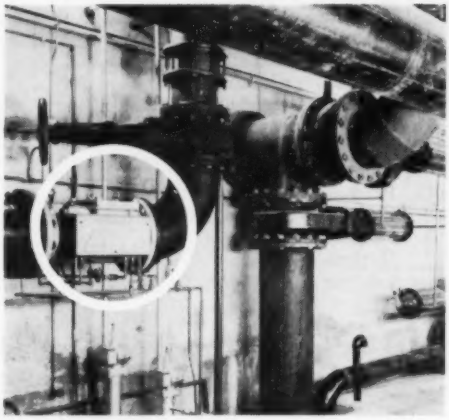
A Type TD transmitter gives accurate readings to within ±1%. It uses no stuffing boxes or relay valves, so both installation and maintenance are simple and economical.

Connected to Simplex Pneumatic Gauges, this new system will give long years of accurate, dependable, trouble-free service.

See our new PN and TD transmitters and the Modulair at Booth 41-44 . . . AWWA Convention, San Francisco — July 12-17

SIMPLEX

a division of PFAUDLER PERMUTIT INC.
Specialists in FLUIDICS . . . the science of fluid processes



FLUIDICS AT WORK

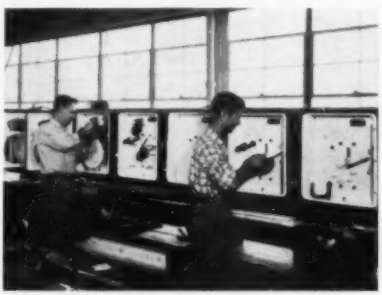
Modulair Flow Controller installs as easily as a piece of pipe

So simple is this new pneumatic rate-of-flow controller, you can install it in about the time it takes to install a piece of pipe.

The differential producer and the modulator lie in a single housing. The actuator is entirely enclosed in a case which mounts directly on the housing.

Result: No complicated piping or drain system to install and maintain.

For a bulletin giving complete specs and performance data, write to our Simplex Division, Lancaster, Pennsylvania. Ask for Bulletin 951.



Fast, dependable delivery insured by new plant

This is the new $2,000,000 home of our Simplex Division . . . an ultra-modern plant designed from front to back to give you fast, dependable service on valves and meters. New manufacturing techniques, updated assembly lines and ample manufacturing capacity and a complete staff of skilled workers have all been planned around the single objective of getting your orders to you on time and built to your exact specifications.

(*Continued from page 64 P&R*)

Water Purification Division Workshop

Task Group Reports
- Membrane Filters ..... J. E. McKee
- Filterability Index ..... Joseph M. Sanchis
- Diatomite Filters ..... E. Robert Baumann
- Radioactive Contamination ..... Harold E. Pearson
- Synthetic Detergents ..... Paul D. Haney
- Filter Backwashing ..... J. E. McKee

Research Reports
- Water Treatment Effect on Main Capacity ..... T. E. Larson
- Protective Coatings for Mains ..... Robert F. McCauley
- Chromium and Cadmium Tolerance ..... R. U. Byerrum
- Coagulation ..... A. P. Black
- Manganese Problems ..... A. E. Griffin
- Chlorine Impurities ..... Thomas DeVries

TUESDAY AFTERNOON, Jul. 14

Water Purification Division

Design Criteria for Rapid Sand Filters ..... *Led by* John M. Jester, W. W. Aultman, John R. Baylis, Richard R. Kennedy & H. E. Hudson Jr.

Short Filter Run Study—Lake Michigan ..... Merrill B. Gamet & John M. Rademacher

Recalcining Water-Softening Sludges—Panel Discussion ..... *Led by* William B. Crow
- Miami, Fla. ..... C. F. Wertz
- Dayton, Ohio ..... Wm. T. Eiffert
- Lansing, Mich. ..... C. R. Erickson

Water Utility Management Division—General Session

Consolidating Water Systems in California ..... John C. Luthin

The Puerto Rico Aqueduct and Sewer Authority ..... Rafael Urrutia

Regional Water Supply Systems
- Developed by the Central City ..... W. W. DeBerard or James W. Jardine
- Developed by District Authority ..... John W. McFarland

Long-Range Weather Forecasting as a Water Supply Tool ..... Irving P. Krick

WEDNESDAY MORNING, Jul. 15

Water Resources Division Workshop

Weather Control ..... F. W. Decker
- Discussion ..... R. S. Millar

Underground Waste Disposal ..... Lynn Miller

Ground Water Recharge ..... John J. Baffa

Erosion Control

Salinity Reduction

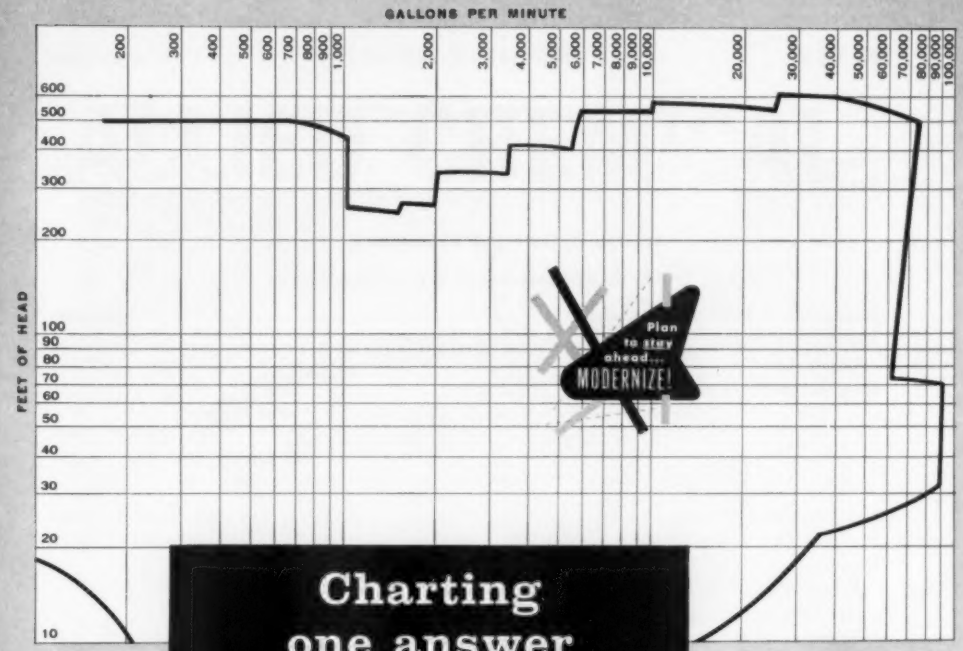
Water Works Administration Committee—Open Session

Report of General Chairman

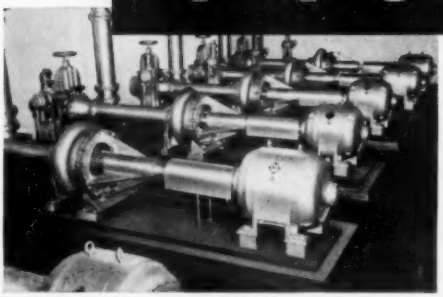
Rating Water Systems—Task Group Report ..... John Murdoch

Job Classifications—Task Group Report ..... Robert S. Millar

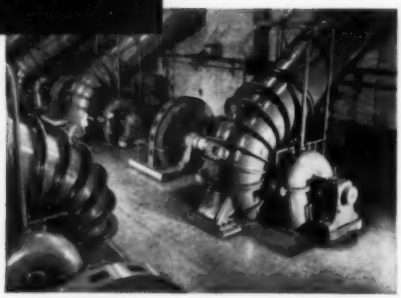
(*Continued on page 68 P&R*)



Charting one answer for every pumping need



Auxiliary service is the job for six 10 x 8 A-C pumps. They are driven by Allis-Chalmers motors.



Main station application involves 12 A-C 72-inch Type SP pumps like that shown.

FROM the smallest auxiliaries to giant, main system pumps, the range chart for Allis-Chalmers pumping units covers practically every public works requirement. One-source equipment availability is a good reason why A-C should be given "first call" in modernizing the pumping facilities.

And complete line is only one "plus" for Allis-Chalmers. Teamed motors and control; standardization of parts and materials; engineering assistance and nationwide service are others.

Whatever your need in centrifugal pumps, contact your representative or distributor. For additional information, write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

A-1023-PW

(*Continued from page 66 P&R*)

Domestic Water Use.....H. E. Hudson Jr.
Pension and Retirement Systems.....John Copley

WEDNESDAY AFTERNOON, Jul. 15

Water Utility Management and Water Distribution Divisions

Mechanics of Bond Election Campaigns.....F. H. Eastman
Maintaining Public Support of Water Works Improvements.....Milton Rosen
Discussion.....*Led by* Robert S. Millar
Railroad and Highway Crossings of Water Lines.....*Led by* Bruce Baty, Edward Clark, R. Robinson Rowe, Herbert Chapton, C. F. Wertz, F. E. Dolson & David Auld

Water Works Practice Committee—Open Session

Cast-Iron Pipe Committee Report.....Raymond J. Faust
Spillway Committee Report.....Raymond J. Faust
Discussions
Plastic Pipe Use
Epoxy Resins as Protective Coatings
Standard Designs and Diagrams for Blocking of Pipe Bends, Plugs, and Fittings
AWWA's Interest in International Standards.....S. Logan Kerr
Research on Water Meter Casings.....H. F. Barrett & Richard C. Reichel
Certification of Water Works Materials.....L. S. Finch & H. E. Jordan

THURSDAY MORNING, Jul. 16

Water Utility Management Division

Blue-Sky Thinking—The Water Works of the Future.....Victor A. Appleyard & William R. Seeger
How Much Does Your Accident Price Tag Show?.....George Sopp
Changes in State Laws Concerning Public Liability.....Gerald Remus
A Quarter Century of Parallel Operation of a Municipal Water Supply and a Public Utility.....Peter C. Karalekas

Water Distribution Division Workshop

The Role of the Corrosion Engineer in the Water System.....Paul Beermann
Distribution of Soil Conductivity and Its Relation to Corrosion.....Gordon N. Scott
Ground Storage *v* Elevated Storage.....Marsden C. Smith
The Effect of Valve Operation on Water Hammer.....S. Logan Kerr
Discussion.....M. B. McPherson

THURSDAY AFTERNOON, Jul. 16

Water Utility Management Division Workshop

Budgeting and Cost Accounting Systems at Work.....J. P. Dieter & C. E. Hemphill
Compensation of Water Works Managers.....Garvin Dyer
Discussion.....Raymond J. Faust
The Need for Demand Meters—Panel Discussion.....*Led by* George H. Dann, W. Victor Weir, M. P. Hatcher & Roy Wehe
Meter Manufacturer's Viewpoint.....W. P. Hersey, M. E. Hartz & J. P. O'Grady

ALLIED CHEMICAL

COLD APPLIED COATINGS
—JOB-MATCHED—

FOR GREATER CORROSION PROTECTION

PRE-PLANNED PRE-MIXED PRE-TESTED

Allied Chemical has taken the guesswork out of choosing the correct coating for your particular job. Now, each Allied Chemical coating is JOB-MATCHED to fit the individual requirements of your job.

For example, Allied Chemical T.O.F. (#114) is a specially compounded coal-tar material for use inside potable water tanks, hydrants and equipment where no residual taste or odor can be tolerated. Meets AWWA Specification D102–55T, Sec. 5.4.6.

You name the area for application and there's an Allied Chemical *JOB-MATCHED* Cold Coating ready to be brushed or sprayed on without heating or activators. Properties include chemical resistance, heavy coating thickness per coat and fast drying.

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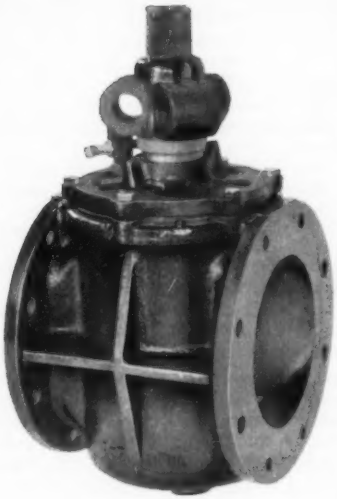

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

DISINFECTION

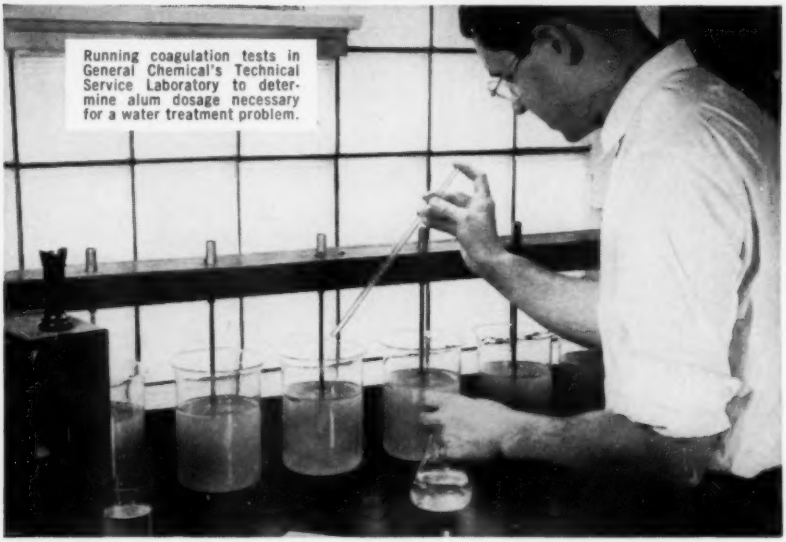
Bacteriological and Chemical Studies on the Influence of the Chemical Composition of Water on the Practical Disinfection of the Hands With Quaternary Ammonium Salts. G. GUNTHER & M. SPROSSIG. Z. Hyg. Infektionskrankh. (Berlin), **142**:416 ('56). Expts. are described about effect of compn., especially hardness, of water on disinfectant action of quaternary ammonium salts in hand cleaning. Expts. were planned to allow signif. statistical calcn. Definite effect of hardness was found. Effects of carbonate and noncarbonate hardness differed. For surgical hand disinfection high deg of hardness, whether carbonate or noncarbonate, is not disadvantage and with some compds. is even advantage. For other hand-cleaning purposes and for instrument disinfection high noncarbonate hardness may be disadvantage and high carbonate hardness advantage. Disadvantages may be removed by using higher concns. of disinfectant or longer periods of contact. Solns. of disinfectants with ampholytic properties were not affected by compn. of water.—*WPA*

Observations on the Failure of Biological Obstruction in the Disinfection of Seepage Water. M. KNORR; F. HAAS; & B. KNORR. Arch. Hyg. u. Bakteriol. (Munich), **140**:130 ('56). Phenomenon of bact. reduction in surface water seeping thru soil depends on distr., straining action, adsorption, and bactericidal effect of change of milieu, chem. substances, and activity of protozoa. Attempt is made to find which of processes act on bacteria underground. It was found that amebae and ciliates can use bacteria as nutrient material only in their vegetative form. Of 300 strains of *Pseudomonas fluorescens* from rivers and water supplies, 64% were found to produce protozoa-resistant (antibiotic) substances. Antibiosis against protozoa is apparently const. property of certain strains. Problem of almost regular appearance of bacilli and *Fluorescens* in ground water is discussed.—*WPA*

Removal of Chemical-Biological-Radiological Contaminants From Water. H. N. LOWE & D. C. LINDSTEN. Military Med., **121**:330 ('57). Lewisite and N mustard were effectively removed from water by slurrying with activated C followed by coagulation and filtration. Nerve poisons were removed by hydrolysis with soda ash and resulting HCN formed were removel by aeration. Biol. contaminants, *Escherichia coli, Salmonella typhosa, Coxiella burnetii,* and *Clostridium botulinum* toxin were removed or inactivated by std. field treatment. Reactor-produced fission products were removed by slurrying with clay, coagulating, clarifying, and filtering. These treatments produced safe, palatable water.—*CA*

The Inactivation of Purified Type 3 Adenovirus in Water by Chlorine. N. A. CLARKE; R. E. STEVENSON; & P. W. KABLER. Am. J. Hyg., **64**:314 ('56). Outbreak of pharyngo-conjuctival fever has been associated with swimming pool in US and causative organism, adenovirus, is believed to be transmitted by swimming pools. It was not previously known whether these viruses were killed by ordinary methods of chlorination. Quant. of purified virus suspension was dild. with demand-free water contg. required amt. of chlorine. After predetd. exposure time 5 ml sample was dild. with equal amt. of twice-normal-strength Hanks's balanced salt soln. contg. 20% chicken serum to neutralize chlorine and inoculated onto HeLa tissue culture. Inactivation time for virus was found to be lengthened at higher pH values or lower temps. but in general was about the same as for *Escherichia coli.* For example, dose of free chlorine of 0.2 ppm at

(Continued on page 82 P&R)



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(Continued from page 78 P&R)

pH 7.0 destroyed 99.8% of virus in 20 sec or less at temps. of 25°C and 4°C. Previous investigations have shown that poliomyelitis, Coxsackie, and infective hepatitis viruses are considerably more resistant. It is concluded that transmission of Type 3 adenovirus thru water in well-chlorinated pool is unlikely.—*BH*

The Chlorination of Water Containing Dysentery Bacteria. V. P. LASKINA. Gigiena i Sanit. (Moscow), **21**:6:9 ('56). Cl dosage and contact time were those usually employed in practice. Of bacteria present in water (*Shigella shigae, S. flexneri,* and *S. sonnei,* along with *Escherichia coli*), *S. sonnei* was most resistant and *S. shigae* least so. In all cases sterilization was complete after 30 min.—*CA*

An Experiment to Treat and to Disinfect Water by Chlorination With Simultaneous Ammonia Treatment in the Water Supply Lines of the Water Trust for the Don Basin (USSR). T. L. NATANSON. Vodosnabzhenie i Sanit. Tekh. (Moscow), **No. 1**: 11 ('58). Simultaneous application of Cl_2 and NH_3 results in stabilization of active Cl, presumably owing to formation of NH_2Cl or $NHCl_2$. H_2O is sterilized and unobjectionable for drinking purposes, and 30–50% less Cl_2 is used than without such NH_3 treatment. This means that such double treatment actually is economical.—*CA*

Water Disinfection at the Vinnitsa (USSR) Water Utility by Chlorination With Intermittent Doses of Chlorine and Subsequent Ammoniation. R. D. GABOVICH & I. A. DRIZ. Gigiena i Sanit. (Moscow), **22**:9:79 ('57). At water utility of Vinnitsa, USSR, river water is treated with intermittent doses of chlorine. After sedimentation for 2 hr, concn. of chlorine is about 0.7–1.2 mg/l. Ammonia is then added in ½ amt. needed to convert chlorine to monochloramine. Greater reduction of odors is achieved by this method than by simple chlorination.—*WPA*

The Inactivation of Spores of *Bacillus globigii* and *Bacillus anthracis* by Free Available Chlorine. A. R. BRAZIS ET AL. Appl. Microbiol., **6**:338 ('58). Spores of *B. globigii* and *B. anthracis* were exposed to free available Cl during contact periods of 2 and 48 hr in solns., pH of which was controlled from 6.2 to 10.5. As pH level increased from 6.2 to 10.5 amt. of Cl require to produce 99.99% kill of *B. globigii* spores increased from 1.9 to more than 450 mg/l (90-min contact period was used). When exposure time was increased from 2 to 48 hr, concn. required to produce 99.99% kill was reduced. Decreasing temp. from 22 to 4°C resulted in 3-4-fold increase in amt. of free available Cl required to obtain 99.99% kill. Amts. of Cl needed to kill *B. anthracis* spores were generally lower than those needed to kill *B. globigii* spores.—*CA*

Removal of Coxsackie and Bacterial Viruses in Water by Flocculation. I. Removal of Coxsackie and Bacterial Viruses in Water of Known Chemical Content by Flocculation With Aluminium Sulfate or Ferric Chloride Under Various Testing Conditions. S. L. CHANG ET AL. Am. J. Public Health, **48**:51 ('58). Study has been carried out in which eff. of alum and $FeCl_3$ in removing Coxsackie and bacterial viruses by flocculation from water of known chem.

(Continued on page 83 P&R)

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(Continued from page 82 P&R)

nature were ascertained and various factors that affect virus-removal eff. of alum flocculation were evaluated. From results obtained and analyzed in this study following conclusions were derived: [1] at 25°C and pH 6.2 maintd. by a bicarbonate buffer, and with stirring rate of 81 rpm, 40 ppm of $Al_2(SO_4)_3$ yielded 86.3% removal of Coxsackie virus and 93.5% removal of bact. virus. Under similar testing conditions 20 and 40 ppm of $FeCl_3$ facilitated 96.6 and 99.3, and 98.1 and 99.9% removal of these viruses, resp. [2] Increase in dosage of alum resulted in corresponding increase in % removal of both viruses. Log-log linear relation existed for both viruses between ratio of % removal of virus to alum dosage and % of virus remaining in settled water. In applying eq. $R = uX^n$, where R is former, and X is latter, and u and n are consts., it was found that values of u were 0.92 and 1.3, and that n values were 0.32 and 0.31 for Coxsackie and bact. viruses, resp. These values indicate that although removal pattern with increased alum dosage is very similar for these two viruses bact. virus is more readily removed than Coxsackie. Dosage-removal relation suggests 2–2½-fold increase in alum dosage for every 10-fold decrease in conc. of virus remaining after treatment. [3] In presence of bicarbonate buffer optimum pH for removal of both viruses by alum flocculation was in 6.2–7.2 range. Lesser removal of both viruses at pH 5.5 occurred with more rapid appearance of floc. At pH 8.2 fairly good floc formation was observed and 80% removal of bact. virus was obtained. Addnl. observation made with 80 ppm of $Al_2(SO_4)_3$ in presence of phosphate buffer showed steady reduction in virus removal with increased pH from 5.2 to 8.2. [4] When rate of stirring was reduced from 81 to 36 rpm during flocculation period removal of Coxsackie and bact. viruses with 80 ppm $Al_2(SO_4)_3$ at 25°C and pH 6.2 (maintd. with bicarbonate buffer) was reduced from 97.1 and 99.1 to 93.6 and 93.8%, resp. [5] When settled floc formed with alum was resuspended in bicarbonate buffer of pH 8.5–9.0 and agitated for 1–2 hr, 60%

(Continued on page 84 P&R)

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(*Continued from page 83 P&R*)

of Coxsackie virus and 10–25% of bact. virus could be dissociated from floc. In separate study attempts to separate these viruses from floc formed with $FeCl_3$ failed.—*CA*

Nerve Gas in Public Water. J. EPSTEIN. Public Health Repts. (US), **71**:955 ('56). It appears reasonable to conclude that, in event of general chem. warfare, nerve gases Tabun and Sarin must be considered potential water contaminants because of very small quants. of these agents required to produce toxic symptoms from ingestion. Hazard due to Tabun, however, is lessened somewhat because of its ease of detection in water by taste, odor, and Cl-demand test. Sarin presents more difficult problem inasmuch as specific detection methods are necessary. Once detected both Sarin and Tabun can be rapidly destroyed by simple means.—*CA*

The Use of Active Iodine as a Water Disinfectant. S. L. CHANG. J. Am. Pharm. Assoc., **47**:417 ('58). Relative cysticidal and viricidal eff. of various species of titrable I and effects of temp. are described. Eqs. are given for computing cysticidal residual I with given contact time and vice versa at varying temps. and for cysticidal residual I in I_2–I_3^- systems.—*CA*

Ozone as a Disinfectant for Water and Sewage. W. STUMM. J. Boston Soc. Civil Engrs., **45**:68 ('58). Information presented gives sufficient evidence that ozone has to be considered as potential disinfectant for water and sewage. Ozone seems to be especially promising with respect to destruction of those pathogenic organisms that are highly resistant toward action of Cl compds., cysts, some viruses, etc. Careful investigation on kinetics of ozone disinfection has been made by Wuhrmann and Meyrath. During each expt. ozone concn. was kept const. by continuously bubbling air contg. small amts. of ozone thru soln. Results indicate that ozone disinfection is mainly function of contact time, concn. of ozone, and temp. of water. Investigations reveal that contact time necessary for 99% destruction of *Escherichia coli*

(*Continued on page 85 P&R*)

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(Continued from page 84 P&R)

is 7 times smaller with ozone than with the same amt. of hypochlorous acid, while killing rate for spores (of *Bacillus megaterium* cereus) is about 300 times larger with ozone than with Cl.—*CA*

Sodium Hypochlorite for Sterilizing Water. Engineering (London), **185**:22 ('58). App., Clorocel, has been devised for continuous electrolysis of brine or sea water to produce sodium hypochlorite soln. for disinfection of condenser and other waters for prevention of algal growths and mussels. Equip. is obtainable with capacs. ranging from 50,000 gal to 1,000,000 gph.—*WPA*

POLLUTION CONTROL

Some Factors Affecting the Aeration of Flowing Water. A. L. H. Gameson & G. A. Truesdale. Water and Sanit. Engr. (London), **6**:52 ('56). Expts. at Water Poln. Research Lab. with water contained in vessels varying in size from beakers to large tanks have shown that certain contaminants —such as sewage effluents and synthetic anionic detergents—lower rate of soln. of atmospheric oxygen. Effect of detergents on rate of aeration of stream free from org. poln. has also been examd. Expts. now reported were made in small channel with object of extending work done in flowing water. Effects on rate of absorption of oxygen that are produced by changing dischg. in channel, and by addn., both separately and together of settled sewage, effluent, and syndets have been studied. Application of these results to conditions in pold. rivers is discussed.—*PHEA*

The Culture of Algae in Residual Waters to Prevent Secondary Pollution in Streams. W. Buckstegg. Bul. Centre Belge Etude et Document. Eaux (Liege), **36**:83 ('57). On the basis of reported studies and published records it cannot be expected that algae can be grown uniformly in stream throughout yr. This is especially true in northern regions.

(Continued on page 86 P&R)

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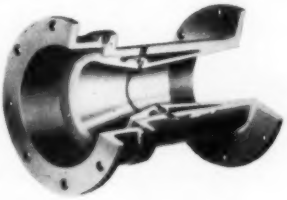

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(Continued from page 85 P&R)

In lat. and climatic conditions of study treatment by algal culture is justified economically for waste waters if massive chlorophyllous blooms are developed in streams whose waters are to be used for domestic supply. Such culture would be possible only if algae could be removed for nutritive or pharmacological purposes. Microscopic algae cannot be removed satisfactorily.—*PHEA*

Anaerobes as an Index of Fecal Pollution in Water. A. T. WILLIS. J. Appl. Bacteriol. (London), **19**:1:105 ('56). Anaerobes were found in much larger nos. than coliform organisms in soil of catchment area of city water supply. Strong case is put forward that anaerobes in water supply do not provide important index of fecal poln. Anaerobic organisms found may have been derived from excreta of sheep, rabbits, birds, etc., deposited over long period. These organisms, being resistant, have survived and *Bacterium coli* and other coliform organisms have died out. It has never been considered that anaerobes are evidence of recent excremental poln., and their use as fecal indicators is usually limited to assessing qual. of underground supplies as distinct from surface supplies. Many of latter sources, when supplied for domestic consumption after complete treatment, including chlorination, may still contain some anaerobic spores. Nevertheless, attempt should be made to reduce these organisms in surface supplies to min. by treatment.—*BH*

Enumeration and Survival of Human Tubercle Bacilli in Polluted Waters. I. Development of Cultural Methods of Enumeration. H. HEUKELEKIAN & M. ALBANESE. Sew. & Ind. Wastes, **28**:955 ('56). Several selective culture methods were tried for enumeration of relatively few tubercle bacilli among great many saprophytic bacteria commonly found in sewage and other pold. waters. Methods tried were: antibiotics incorporated in culture medium, pretreatment of sample by controlled chlori-

(Continued on page 87 P&R)

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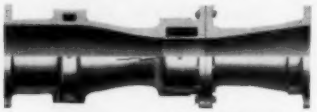

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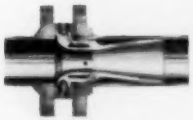

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(*Continued from page 86 P&R*)

nation, and pretreatment of sample with Bradasol, a quarternary ammonium compd. Criterion of success was complete suppression of saprophytes with effect on recovery of tuberculosis organisms such that presence of pathogen could be detected in 1 ml of original sample. Work was done by artificial inoculation of sewage with *M. tuberculosis* (*hominis*). Results warrant following conclusions. [1] Penicillin and grisein used in amt. of 100 units/ml did not effect recovery of tuberculosis organism, but at 125 units/ml these antibiotics completely suppressed it. At 100 units/ml sufficient suppression of sewage saprophytes was not obtained to make suitable selective culture medium. [2] Terramycin (both hydrochloride and sulfate) in amts. of 1μg/ml greatly reduced recovery of tubercle bacilli, but it did not satisfactorily suppress sewage organisms. With 10 μg/ml concn. suppression of sewage organisms was substantial (96%) but so was suppression of tubercle bacilli. Chloramphenicol was even less satisfactory than terramycin. This antibiotic in concns. of 1 μg/ml had very little effect on either sewage saprophytes or tuberculosis organism; 10 μg/ml suppressed pathogen completely and saprophytes substantially. [3] Chlorination of sample to orthotolidine residual of 0.5 and 1.0 ppm after 30-min contact period gave substantial but not complete suppression of sewage saprophytes and 50% recovery of *M. tuberculosis* (*hominis*). [4] Pretreatment of sample with 500 ppm of Bradosol for 20 min gave complete suppression of sewage saprophytes and 70–80% recovery of *M. tuberculosis* (*hominis*).—*PHEA*

Biochemical Degradation Products—A New Dimension in Stream Pollution. R. H. Bogan. Purdue Univ., Eng. Bul. Ext. Ser., No. 94:317 ('57). Although BOD detn. gives evidence as to amt. of residual org. matter to be expected in effluent, it is not to be assumed that residue is identical to original pollutant. Infrared anals. of effluent from activated sludge fed with *p*-dodecylbenzenesulfonate and with kerylbenzenesulfonate showed presence of aromatic

(*Continued on page 88 P&R*)

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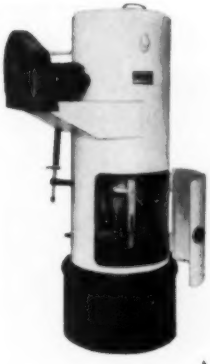

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alcs., ketones, aldehydes, and acids. Presence of benzene nucleus tends to slow degradation. Presence of oxidation intermediates may be problem in water treatment.—*CA*

Biological Assessment of Pollution in Birmingham Streams. H. A. HAWKES. J. Inst. Munic. Engrs. (Br.), **82**:425 ('56). Biol. method of detg. nature and amt. of stream poln. by biol. assessment of flora and fauna in ecologically similar reaches is described. Shallow rapids having fairly stable stony bed are examd. Procedure for collections is described and frequency of species is described as abundant, frequent, occasional, rare, or absent. As nature of stream bed community reflects past qual. of water flowing over it, relatively infrequent examns. are as informative as more frequent chem. examns. Reference to Kolkwitz and Marsson's classification of organisms according to their assoc. with varying deg of org. poln. enables both growth on stones and larger organisms to be divided into 4 classes.—*CA*

Clarification of Highly Poluted Water in Algeria. G. BERGEZ. Tech. sanit. et munic. (Paris), **51**:179 ('56). Various experiences with highly pold. waters in Algeria have led to series of special treatment processes in purif. of water. Certain types of fine sediments are more easily removed when sedimentation chambers are vertical.—*PHEA*

Laboratory Studies on the Application of Activated Ashes to Water Coagulation. J. GANCZARCZYK. Gaz, Woda i Tech. Sanit. (Warsaw), **32**:92 ('58). Ash from some coals, activated with H_2SO_4 appears to be more useful for treatment of natural or industrial sewage than $Al_2(SO_4)_3$. Owing to its high sorptive power it can be used to remove low concns. of org. impurities. High rate of sedimentation and low costs present addnl. advantages.—*CA*

Synthetic Detergents and Water Supplies. C. HAMMERTON. Proc. Soc. Water Treatment Examn. (Br.), **5** ('56). 1st part discusses presence of syn. dets. in rivers and

(Continued on page 89 P&R)

POSITIVE CONTROL OF *MATERIALS IN MOTION* BIF METERS FEEDERS CONTROLS

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(Continued from page 88 P&R)

their effect on water treatment processes. 2nd part is review of structure of surface-active compds. in relation to their susceptibility to biol. breakdown. In 1st half of '56 the avg. concn. (in terms of Manoxol OT) in Thames R. was almost 0.4 ppm and in Lee R. 0.5 ppm. As result detergent is still present in tap water. Typical "built" detergent contains great proportion of phosphates and there has been corresponding increase in concn. of phosphate in these rivers. Author showed that 20 ppm of no. of syn. dets. (as marketed) had no effect on selected std. methods of water anal. Concn. of detergent which has reached river in sewage effluents diminishes in its passage downstream, as is shown by author's anals. of Lee R. Nevertheless, author considers that presence of surface-active material in river used for water supply has tendency to make that supply slightly inferior to what it otherwise would be. Series of tests was carried out on lab. and pilot scale to det. effect of small doses of these detergents on normal processes of water treatment. Results may be summarized: [1] Storage of river water reduces concn. of surface-active material by 20–50%, depending on length of storage and prevailing weather conditions. [2] Slow sand filtration (4½ in/hr) also reduces concn. by about ½. Combination, therefore, of storage and slow sand filtration—treatment used by Metropolitan Water Board—would achieve, under most favorable conditions, reduction of about 75%. [3] Treatment of hard river water with aluminium sulfate and activated silica followed by rapid filtration showed that coagulation had no effect on detergent concn. and that filtration had only very small effect. [4] Very large doses of powdered activated carbon removed substantial proportion of surface-active agents. [5] Neither fuller's earth nor softening with lime-soda reduced detergent concn. [6] Prelim. expt. indicated that bactericidal effi. of chlorine was not affected by about 4 ppm of detergent, which was also unaffected by chlorine in normal water treatment doses. From these expts. author concludes that treatment processes at present used by Metropolitan Water Board

(Continued on page 90 P&R)

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(Continued from page 89 P&R)

will not be adversely affected by these detergents at present or foreseeable concn., but treatment does not entirely remove them and this is undesirable on esthetic, if not on health, grounds. Early anionic detergents available in Br. were secondary alkyl sulfates which were readily broken down during sewage treatment. From about '49, however, household detergents based on alkyl benzene sulfonates became increasingly common and these were not readily degraded biologically. This led author to investigate which property of these agents governed their susceptibility to biol. oxidation. Owing to impossibility of obtaining active material of many of these detergents in high deg of purity author also exptd. on analogous compds. which were not surface-active. His results are given in 2nd part of this paper and in earlier paper. Author concludes from his expts. that primary or straight-chain compds. are readily broken down, secondary groups less readily, and that tertiary carbon groups are resistant to bact. oxidation. This conclusion is supported by much Am. work. Same principle appears to operate when methyl groups are introduced into NH_2 groups. Author has also carried out prelim. expts. to det. whether it might be possible to produce surface-active compds. in which link between hydrophilic and hydrophobic groups was susceptible to bact. attack.—*BH*

Continuing Research Related to Detergents in Water and Sewage Treatment. H. V. Moss. Sew. & Ind. Wastes, **29**: 1107 ('57). In '56 research was initiated at 4 univ. by Assoc. of Am. Soap and Glycerine Producers. This paper is progress report briefly reviewing research projects. Alkyl-benzine sulfonate (ABS), predominantly org. constituent of syndets apparently has greater resistance to biodegradation. M.I.T. research indicates that variety of common soil-born bacteria normally found in activated sludge can utilize ABS and that ABS present in concns. normally found in domestic sewage is not toxic to activated sludge bacteria. Univ. of Calif. project reports that in normal sewage treat-

(Continued on page 92 P&R)

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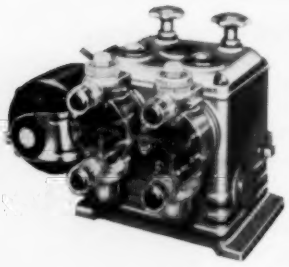

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(Continued from page 92 P&R)

ment range in ABS concn. which might be expected in sewage produces no important effect on % of ABS removal, and agrees with M.I.T. work in regard to nontoxic effect of ABS to activated sludge bacteria. Syndets have been blamed for problem of frothing in sewage treatment plants. Research project at Univ. of Wis. is seeking causes of frothing and means of elimg. or minimizing nuisance. To date, studies as to cause of frothing suggest that frothing has no effect on plant efficiency. Frothing was more prevalent during periods of low flow and indication that increase in org. nitrogen cont. contributes to frothing tendencies. Accurate and relatively simple methods for anal. of ABS in low concns. are not available and some progress is noted, but practical method for phosphate anal. has been proved out and is being perfected. Univ. of Ill. project is comprehensive survey of levels of phosphate presently existing in surface waters. From another source evidence has been found that indicates that polyphosphates do not find their way into raw waters in sufficient concn. to pose real problem to water treatment operations.—*PHEA*

The Consumption of Dissolved Oxygen as Legal Test of Water. P. BEAUJEAN. Bul. Centre Belge Etude et Document. Eaux (Liege), **65**:192 ('56). Measurement of consumption of DO in 48 hr at 20°C of river water in vicinity of purif. plant intake is simple. Measurement of obscurity is stipulated by Office of Water Purif. Method of measurement of BOD of industrial effluent subject to authorization of dischg. is standardized. Precision of method is discussed. Making of measurement of industrial pollutant charge by BOD test does not imply ability of dischg. this into river where these phenomena appear different.—*PHEA*

Removal From Water of Dissolved Organic Contaminants, in Clarifiers With Suspended Alumina-Charcoal Layers. L. A. KUL'SKII ET AL. Ukrain. Khim. Zhur. (Kiev), **22**:112 ('56). Water contamd. with phenol is passed upwards, together with charcoal suspension stabilized with 10% of $Al(OH)_3$, through suspended layer of same adsorbent, which is removed for recycling at same rate. Water from above adsorbent layer is passed similarly thru further clarifiers, in series, until concn. of phenol is

(Continued on page 94 P&R)

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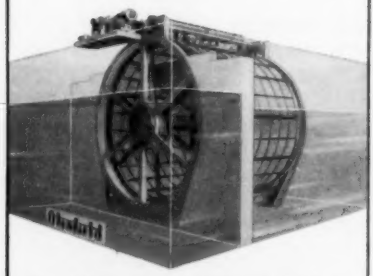

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(Continued from page 90 P&R)

reduced to desired level. Expenditure of charcoal is low enough to render process feasible for purif. of industrial effluent waters.—*PHEA*

Potential Infection From the Drinking Fountain. W. L. MALLMAN & A. K. FONTES. A.M.A. Arch. Ind. Health, **16**:77 ('57). Survey of drinking fountains of various designs in public places was made. 4 types were checked: bubble, vertical jet, angle jet without guard, and angle jet with guard. Bubble fountains were found to be easily contamd. resulting in contamn. of water. Angle jet fountains contamd. to lesser deg yielding water which was mostly uncontamd. in unshielded type and very slightly contamd. in shielded type. Further tests indicated that aerosols are formed as result of splashing of water in bowl of fountain. When source of bacteria is present—as it is when person drinks—these aerosols are heavily contamd. These aerosols will scatter and contam. immediate area of fountain and set up secondary contamn. in orifices and shields of fountains.—*PHEA*

Hygienic Evaluation of Formaldehyde as a Factor in the Pollution of Reservoirs. I. V. NAZARENKO. Gigiena i Sanit. (Moscow), **23**:1:3 ('58). Odor of HCHO is detectable at 20 mg/l; at 5 mg/l it has very little effect on oxidation of NH_3 but does affect conditioned reflexes of rats. Max. of 0.5 mg/l is proposed as safe.—*CA*

Activity of Cellulose-Decomposing Fungi Isolated From Sewage-Polluted Water. W. B. COOKE & K. A. BUSCH. Sew. & Ind. Wastes, **29**:210 ('57). Fungi capable of using cellulose as sole carbon source are present in sewage-pol. waters. Inocula of fungus mycelia are less effective in aiding the reduction of cellulose than inocula of spore suspensions when growth medium is raw sewage. For other media, spore suspension inocula are somewhat less effective. This may be related to conditioning of inocula: Raw settled sewage appears to contain organisms capable of utilizing cellulose as carbon source in presence of other organisms which may remove toxic substances and/or provide growth-promoting substances. —*PHEA*

(Continued on page 98 P&R)

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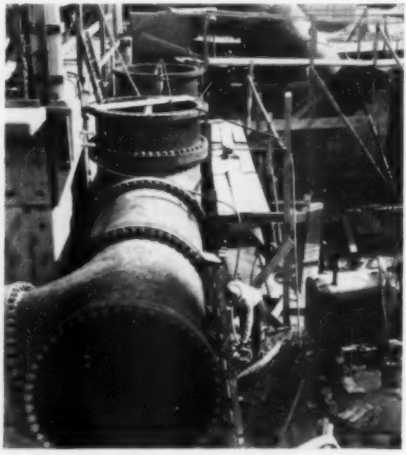

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(Continued from page 94 P&R)

Goldfish Are Good Sanitary Inspectors. J. E. MILLER & G. F. ULLRICH. Petrol. Engr., **28**:C9 ('56). Air and water poln. control at Baton Rouge, La., refinery; system of lines installed to accumulate spent caustics and emulsifying agents from process operations; treatment of emulsions; earthen separator 20 ft deep, 300 ft wide, and 800 ft long was built to furnish addl. settling time; goldfish are used as test animals; smoke abatement, removal of hydrogen sulfide, sulfur dioxide, and hydrocarbons released.—*PHEA*

Experimental Ground Water Pollution at Anchorage, Alaska. H. J. FOURNELLE; E. K. DAY; & W. B. PAGE. Public Health Repts. (US), **72**:3:203 ('57). Underground water poln. is of prime importance to public health officials concerned with safeguarding potability of water supplies. Expts. described in this paper were devised to study lateral movement of simulated bact. and chem. pollutants thru ground water in Alaskan area with soil of sandy-gravel texture for at least yr. Method of study employed was to dig dosing well surrounded by ring of 9 sampling wells about 3 ft away. Dye uranin (sodium salt of fluorescein) as test agent was introduced into dosing well and examn. for uranin of waters in sampling wells indicated after about 2 days direction of flow of underground water. 5 or 6 wells were then placed in arcs at 5–10 ft intervals up to about 100 ft away in direction of dye movement. As coliform organisms, although commonly employed in ground water poln. studies, had been found in soil of test site it was decided to use 3 chromogenic bacteria in combination and enterococcus. Organisms chosen were *Serratia marcescens* [*Chromobacterium prodigiosum*], *Streptococcus zymogenes*, and *Chromobacterium violaceum* and 2 strains of *Bacillus globigii*. Method of study and its results are fully described. Uranin was found to be very satisfactory for detg. direction of flow of ground water. It was traced 100 ft from point of dosing and was detected 2 yr and 10 mos. later. *Str. zymogenes* was found to be suitable as tracer organism and

(Continued on page 100 P&R)

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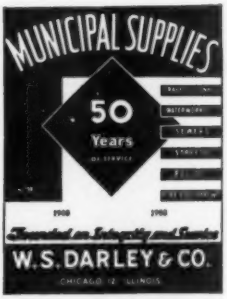

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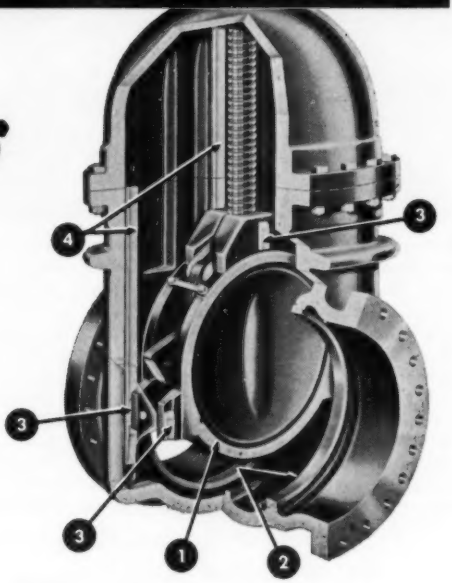

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(Continued from page 98 P&R)

was isolated from water 50 ft away from dosing well. Chromogens were not found to be suitable as test agents. In order to det. period of survival of test organisms broth cultures were placed in dialysing sacs and suspended in dosing well. These sacs were examd. after exposure times varying from 24 hr to 1 yr. *Str. zymogenes* was found to survive for yr although nos. of living organisms had been reduced from about 150,000,000 to about 5,000/ml.—*BH*

Pollutional Effects of Hydraulic Power Generation. R. S. INGOLS. Sew. & Ind. Wastes, **29**:293 ('57). Deterioration in water qual. due to storage behind hydroelectric dams may be expressed as a pop. equiv. on BOD basis of as much as 1,000,000 people for Duke Power Co. dam on Catawba R., S.C. Oxygen depletion in stored water is due primarily to biochem. activity in waters below thermocline. These colder waters are dischgd. from turbine and returned to stream with little or no DO and may contain manganese or sulfide. Operating schedule of power plant is such that min. flows obtained during periods of low power demand further limit capac. of stream to receive wastes from persons discharging wastes downstream. These factors tend to offset advantages of impoundment, which include less sediment, color, and bacteria, and lower temp. at point of dischg.—*PHEA*

Purification of Water Containing Hydrogen Sulfide by Activated Carbon. A. SWINARSKI & Z. SKALECKI. Przemys Chem. (Warsaw), **37**:91 ('58). Waste water contg. H_2S has been purified by percolating it through activated C in packed lab. column while air (30–40% excess) was blown into column countercurrent to flow of water. H_2S was catalytically oxidized to S with yields more than 97%. Max. rate of oxidation was 2×10^{-4} g H_2S/g of C/min. Such good desulfurization of waste water corroborates theory that S ions and not H_2S were oxidized. Authors computed that column contg. 1,200 kg of activated C could purify 100–140 cu m of pold. water.—*CA*

(Continued on page 102 P&R)

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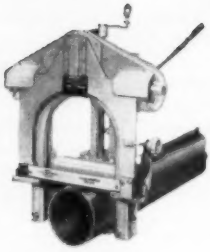

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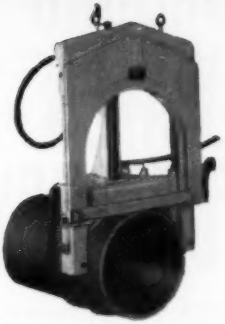

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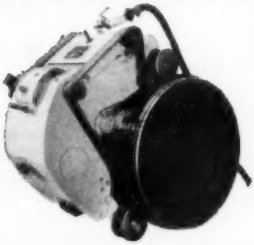

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(Continued from page 100 P&R)

Correcting Storm-Water Infiltration at Tonawanda, N.Y. N. L. NUSSBAUMER. Sew. & Ind. Wastes, **29**:977 ('56). Article describes layout and constr. of early sewers at Tonawanda, N.Y. Improper planning, poor constr., lack of storm sewers, and diversion of surface water into sanitary sewers caused flooding of sanitary sewers during periods of ppn. Increased tributary pop. intensified sewer problems. Several attempts were made to remedy situation. In '45 comprehensive storm drain plan was developed to elim. excess water from sanitary sewers. Types of storm sewers used, design criteria, constr. details, and costs are outlined.—*PHEA*

The Hygiene of Water Supplies and Local Inspection. P. HOFMANN. Desinfekt. u. Gesundheitsw. (W. Ger.), **49**:37 ('57). Author discusses unimportance of risk of poln. of ground water from cemeteries. Septic pit is more dangerous neighbor to water utility than cemetery is. Recent epidemics in Ger. caused by infection of water supplies are described. Drinking of infected water appears to be not so dangerous as its use for washing vessels used for food. Methods of disinfection of water supplies are described and risks of poln. of ground water by oil are discussed. Hygienic local investigations are of more importance than bact. examn.—*WPA*

Methods for Maintaining the Quality of Bottled Mineral Waters. T. SLAVE & C. FINAT. Lucrarile Inst. Certetari Aliment. (Hung.), **2**:135 ('58). To prevent deterioration of qual. of bottle mineral water upon storage several methods were investigated. Water was satd. with CO_2, stabilized with colloids, and some or all of Fe was removed. If bottling occurred under atmospheric pressure satn. with CO_2 at 2–3 atm. did not serve any purpose, if water was not chilled before such treatment. Water should never contact air in these tests, i.e., not absorb O_2 during act of bottling. Colloidal stabilization with small amts. of org. acids found in foods (citric, tartaric, etc.) gave good results for water low in SO_4^{--}. If SO_4^{--} was present this treatment was definitely ruinous, as microflora present causes formation of H_2S. Fe can be removed in part or completely without bringing about any other important chem. change, by treatment with 3% H_2O_2, or by aerating it in closed system in pres-

(Continued on page 104 P&R)

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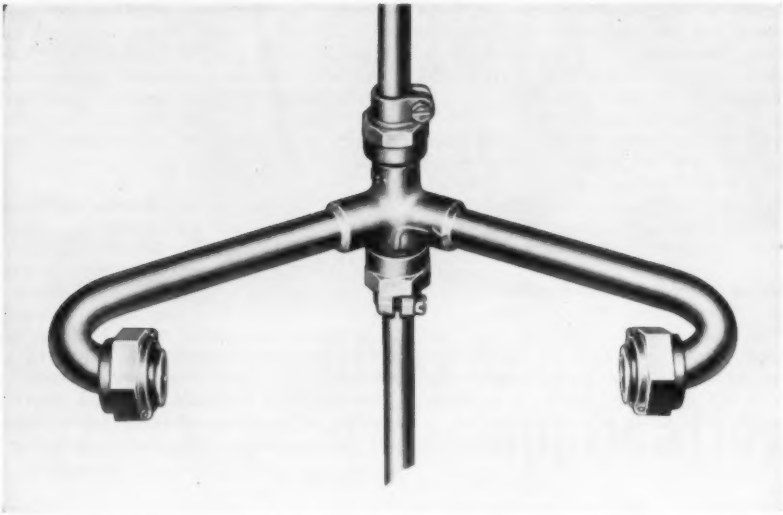

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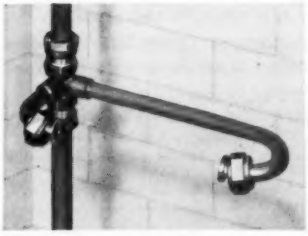

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(Continued from page 102 P&R)

ence or absence of CO_2. For this latter process an app. is shown that can be used for continuous removal of Fe.—*CA*

Pollution of Natural Waters by Petroleum Products and the Possibility of Their Analytical Detection. B. NIETSCH. Gas, Wasser, Warme (Vienna), **10**:66 ('56). Automobile oil, crude oil, cylinder oil, and 2 types of transformer oil were tested to discover whether they could be used under ultraviolet light to indicate extent of oil poln. of ground waters. Using diffuse light methods it was demonstrated by fluorescence that there was fairly large ground water poln. in vicinity of a tar factory.—*PHEA*

Pollution Control in New England. W. S. WISE. Sew. & Ind. Wastes, **30**:86 ('58). In New Eng., water problems have not received proper attention or recognition. Stream poln. control has lagged because such work is not glamorous, public is apathetic, there are other more powerful demands on public funds, and industry is reluctant to participate financially. Water poln. control efforts of individual states made it apparent that interstate coordinated program was essential. Accordingly, New Eng. Interstate Water Poln. Control Commn. was formed in '47. Commn. is composed of 5 members each from Conn., Mass., R.I., N.Y., Vt., N.H., and Me. Commn's. activities have included beneficial use stream classification system and numerous research projects on various aspects of industrial wastes treatment problems.—*PHEA*

Harmful Contents of Nitrate in Water Supply. G. GAD & K. NAUMANN. Gas- u. Wasserfach. (Munich), **97**:684 ('56). Authors discuss occurrence of nitrate in water supplies and its importance as indicator of poln. and as harmful constituent of supply. Considering permissible cont. of nitrate, they point out that mistakes have arisen by assuming that limit often recommended in Am. technical literature of 10 ppm refers to nitrate, whereas according to Am. *Standard Methods* nitrate cont. in water and sewage is

(Continued on page 106 P&R)

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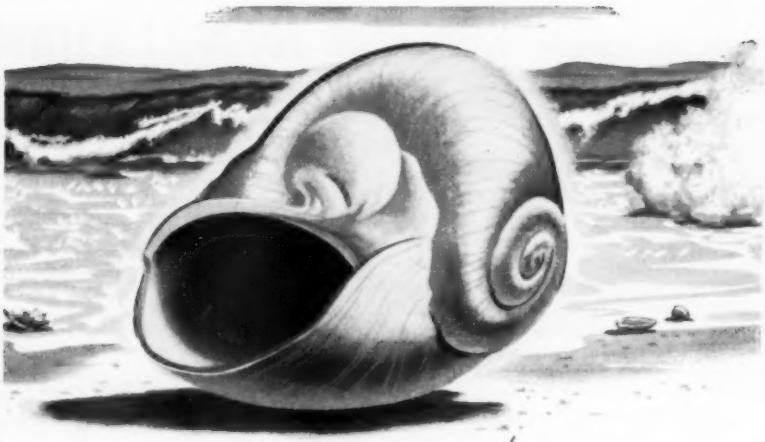

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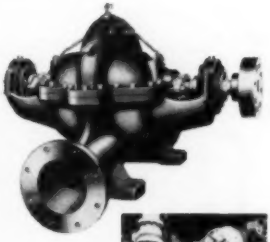

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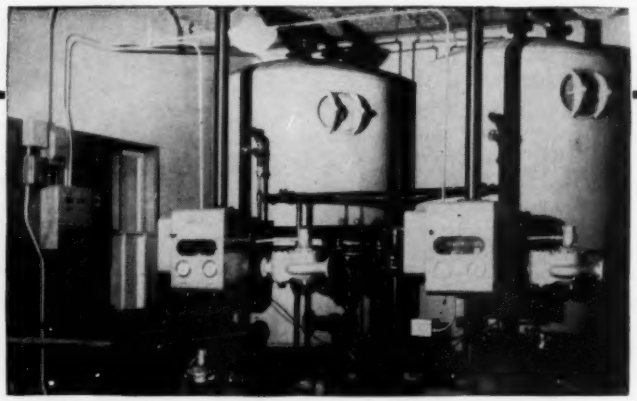
(Continued from page 104 P&R)

expressed as nitrate-nitrogen. Authors recommend limit not exceeding 40 ppm. Chem. and biol. methods for removal of nitrate are mentioned.—*WPA*

Soil Nitrification and Nitrates in Waters. E. L. SCHMIDT. Public Health Repts. (US), **71**:5:497 ('56). It has been established that methaemoglobinaemia may be caused in very young infants, usually less than 2 mos. old, by ingesting water with high nitrate cont. High nitrate cont. may result from variety of causes, and survey reported here had as its object obtaining information on possible relationship between nitrate accumulation in waters and nitrate production in soils. Clear acct. is given of planning and methods of survey. Data of nitrate concn. in 39 well waters (depth of wells generally 15–50 ft) from 26 sites in 4 counties of Minn. were obtained and samples of 59 surface soils and 50 subsurface soils associated with these waters were also examd. Surface soils were also studied for capac. to produce nitrates. Data from the anals. are set out in tables. It was found that nitrate cont. of some waters fluctuated significantly and it is considered that the fluctuations were due to soil leaching associated with rainfall distr. Water supplies with highest concns. of nitrate (75–130 ppm) were located near soils obviously contamd. with org. nitrogen by livestock. Such soils had highest nitrifying capac. Field soils in pastures, sod or under cultivation were generally but not invariably much lower in nitrifying capac. Some soils of high nitrifying capac. may contribute to nitrate cont. of water supplies from wells ordinarily considered to have been located in satisfactory position.—*BH*

Desorption of Some Long-Lived Radioisotopes From Bottom Sediments. B. A. STEPANOV. Gigiena i Sanit. (Moscow), **22**: 11:3('57). Soln. of radioisotopes was shaken with sample of mud and then mud extracted with H_2O of various pH values and salt conts. Radioactive material was still being removed after 30 extractions. Contamd. river and res. bottoms would probably be cause of contamn. for long time.—*CA*



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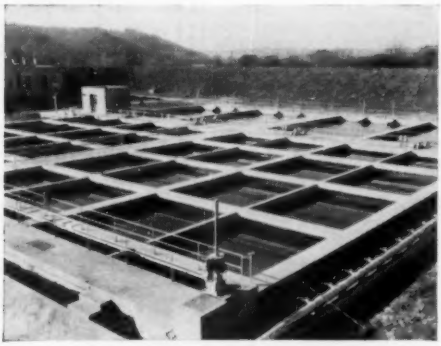
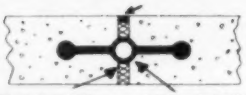
WATER LEAKAGE PROBLEMS IN CONCRETE STRUCTURES?



SPECIFY AND USE . . . RUBBER WATERSTOP

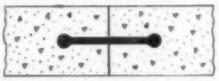
HOLLOW BULB—FOR EXPANSION JOINT

Insures permanent, watertight seals in joints where considerable movement due to expansion and contraction is expected. Flexible and elastic with a very high degree of tensile strength to withstand both lateral and shearing movement. Widths—6" and 9" . . . lengths to order.



FLAT DUMBELL—FOR CONTRACTION OR EXPANSION JOINTS

Made of durable, elastic cured rubber which has high tensile strength and flexibility for effective sealing of contraction and expansion joints against hydrostatic pressure. Carefully manufactured to insure dense, homogeneous cross section for greatest service life. Widths—6" and 9" . . . lengths to order.



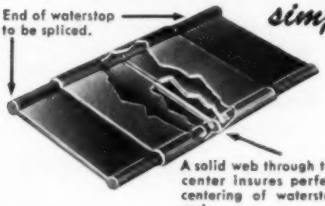
SPLIT TYPE WATERSTOP

faster, easier installation

A new Servicised development already in wide use because it reduces installation time and cost by eliminating splitting of form. One half of width is split to permit fastening to inside of bulkhead in the form of a "T." After section is poured, form is removed and divided sections are joined together by stapling. Pat. Pend.

WATERSTOP UNION

simplifies Field Splicing



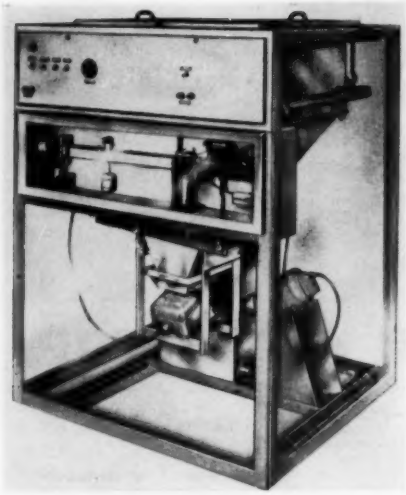
Permits a faster, simpler method of field splicing, using only rubber cement. The union is hollow and is made from rubber meeting the same specifications as the waterstop. Available for splicing 6" and 9" Dumbbell and 6" and 9" Hollow Bulb Waterstops. Pat. Pend.

Write for Special Waterstop Catalog.

SERVICISED PRODUCTS CORPORATION

6051 West 65th Street **Chicago 38, Illinois**

(Continued from page 62 P&R)



An electronically controlled dry feeder said to provide reliable, continuous volume feeding at any rate between 3 and 300 lb/hr is being marketed by Syntron Co., 428 Lexington Ave., Homer City, Pa. In operation, a weighed batch of material is loaded into the machine's 9-cu ft stainless-steel hopper mounted on a beam scale. The material is discharged at a predetermined rate by an electromagnetic vibrator electronically controlled by the weight of the material in the hopper.

Just Add Water continues to grow. Fill a new fountain pen with water and it writes with ink. Guaranteed for ten fillings—50 hr of writing—it sells for $1.49. Refills of the ink concentrate cartridges cost 29 cents, of the water????

Earl Devendorf has retired as director of the Bureau of Environmental Sanitation, New York State Dept. of Health, Albany, a post he had held since 1948. A Life Member of AWWA and recipient of the Diven Medal and the Fuller Award, he has a total of more than 40 years of service with the department.

James C. Lamb III has been appointed associate professor of sanitary engineering at the University of North Carolina, Chapel Hill. Since 1955 he had been responsible for the technical aspects of American Cyanamid's industrial-waste treatment program at Bound Brook, N.J.

John W. Krause, water superintendent at La Grange, Ill., has retired after more than 20 years' service. It was largely through his efforts that the city became the first in the United States to operate a zeolite-softening facility successfully.

(Continued on page 110 P&R)

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In conformity with A.W.W.A. specifications for filtering material or made to your own specification.

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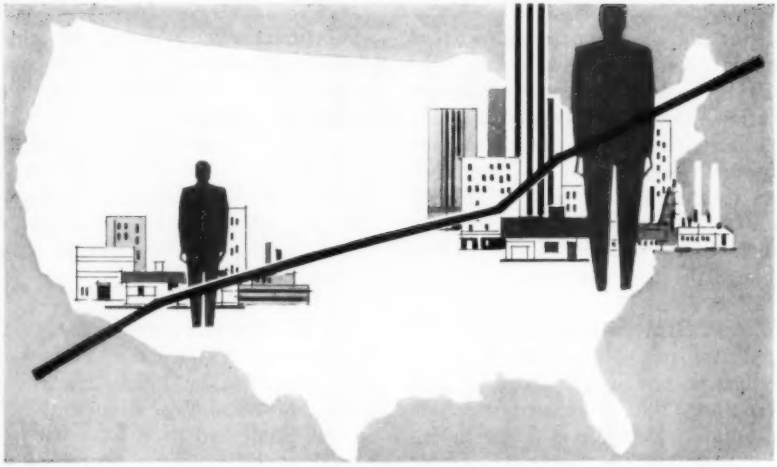
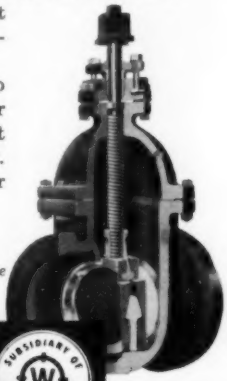


PEOPLE AND WATER

Two things mostly have brought about America's present water problem: Increasing population and progress of human civilization. Both are cumulative and therefore will surely produce greater water problems in the future.

Ancient Man simply knelt beside a stream and drank water like any other animal. But for one human who existed in the time of Moses, there now are millions. Today, the fastest growing population in the world is in America. It is estimated the U. S. population by 1975 will be 227 million. Present water consumption is 140 gallons per capita per day and steadily increasing. The Earth's total volume of water is abundant. Man's problem is to capture and purify enough of it at one time during the hydrologic cycle to serve his increasing needs due to the progress of civilization.

Water is the natural resource most essential to human survival, yet public support of modern water development and research has been lacking. Don't let your water works superintendent do all the worrying. He has big plans for the future. But, he needs your help and encouragement.



This Series is an attempt to put into words some appreciation of the water works men of the United States.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF W WALWORTH

(Continued from page 108 P&R)

Reflecting the importance of water pollution control activities in the USPHS, a new Division of Water Pollution Control has been established. These activities were formerly carried on by the Water Supply & Water Pollution Control Branch of the USPHS Div. of Sanitary Engineering Services. Branch Chief Gordon E. McCallum will head the new division.

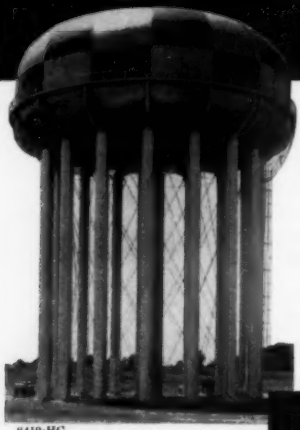
John P. Brownstead, utilities director at Ashland, Ky., died Mar. 30, 1959, at the age of 68. Born in 1891 in Ironton, Ohio, he joined the Ashland Water Dept. in 1919. In his more than 20 years as water works director ("utilities director" since 1957), his abilities and training—he was both a registered engineer and a graduate accountant—enabled him to render invaluable service in the growth and development of the city's water system. He also served recently as acting city manager.

An AWWA member since 1938, he received the Fuller Award in 1941 on nomination by the Kentucky-Tennessee Section. He also belonged to the National Society of Professional Engineers.

H. R. Cady, retired engineer for Hackensack Water Co., Weehawken, N.J., died Apr. 11, 1959. He was 73. Born in 1886 in East Chatham, N.Y., he was graduated from Syracuse University in 1901 with a degree in mechanical engineering. In 1910, after a number of years in the railroad field, he became an instructor in mechanical engineering at the University of Penn-

(Continued on page 114 P&R)

STOP CORROSION . . . IN WATER STORAGE TANKS



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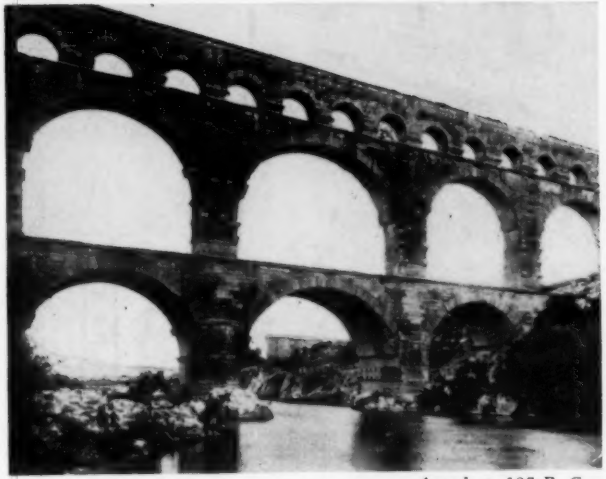
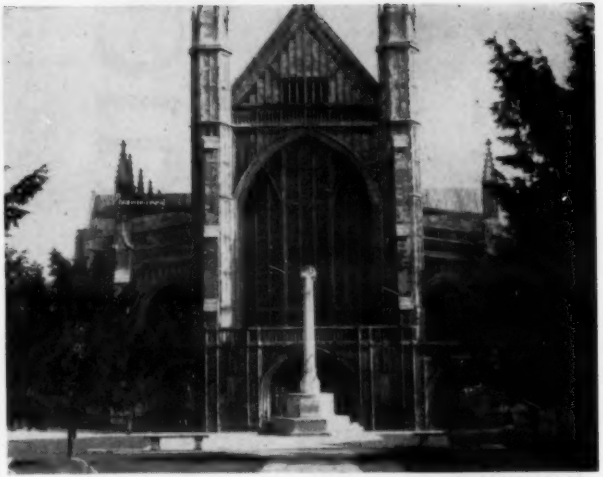
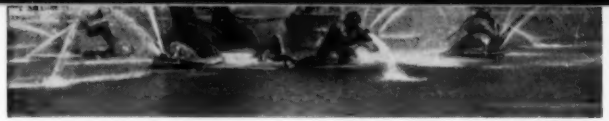


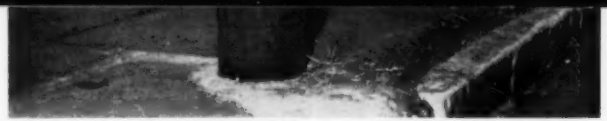
Aqueduct, 105 B. C.



Cathedral, 1065



Fountain, 1650



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Developed through nearly 100 years of practical experience, Ludlow and Rensselaer hydrants have *earned* their title of "watchdogs of American property." Without exception, they give you the 4 basic requirements for hydrant performance: simplicity of design, absolutely tight closure, no freezing and no flooding due to standpipe breakage.

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LUDLOW & RENSSELAER

VALVES AND HYDRANTS

THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N.Y.—SINCE 1861

(Continued from page 110 P&R)

sylvania. From 1913 to 1927 he was employed by the Philadelphia Water Dept. in various engineering capacities. In 1927 he joined Hackensack Water Co., and at the time of his retirement in 1951 he was responsible for the operation and maintenance of all of the company's pumping facilities. Mr. Cady had been an AWWA member since 1929.

Frank M. Evans, borough engineer for both Glen Rock and Ho-Ho-Kus, N.J., died in April 1959 while on vacation in Florida. He was 71. Born in Morton, Pa., he held a degree in civil engineering. He was named borough engineer at Glen Rock in 1916 and since 1927 has simultaneously served in the same position at Ho-Ho-Kus. An AWWA member since 1946, he also belonged to ASCE.

Theodore D. Faulks, retired consultant for Neptune Meter Co., New York, died Mar. 7, 1959, at the age of 88. Born in Elizabeth, N.J., he was associated with Carroll P. Bassett, civil engineer, in the construction of a number of municipal sewer systems in New Jersey before taking the post of superintendent with West Orange (N.J.) Water Co. in 1892. In 1900 he became manager of Clinton Water Co., Irvington, N.J. Joining Neptune Meter Co. as a sales engineer in 1903, he remained there until retirement in 1934, and for 6 years thereafter served the firm as consultant. He had been an AWWA member since 1937.

(Continued on page 116 P&R)

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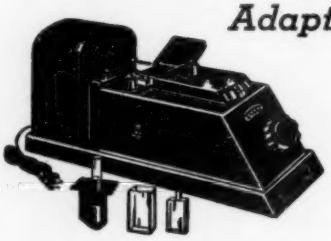
Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

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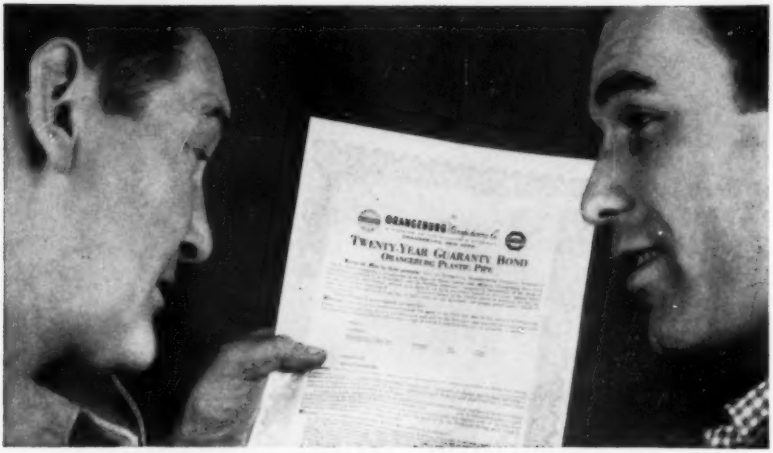

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Under terms of Bond, repairs or replacements, INCLUDING LABOR COSTS, *due to failure of pipe will be made at Orangeburg's expense. You can't lose.*

And it's easy to apply for the Bond. When Orangeburg *SP* installation is completed, send *"Request for Bond"* Form to Orangeburg. After approval, Bond is sent direct to your customer.

Be first to cash-in with Orangeburg *SP* Plastic Pipe and the exclusive iron-clad 20-year Guaranty Bond offer. See your Authorized Orangeburg Wholesaler or write Dept. JA-69.

Approved for drinking water by National Sanitation Foundation NSF LIFE

ORANGEBURG MANUFACTURING CO. • Orangeburg, N. Y. • Newark, Calif.
A Division of The Flintkote Company, Manufacturers of America's Broadest Line of Building Products

(Continued from page 114 P&R)

Frank E. Harley, civil engineer, Wyckoff, N.J., died in April 1959 at the age of 66. Born in 1892 in Paterson, N.J., he received a B.S. from Cooper Union in 1921 and a degree in civil engineering in 1928. Before taking up private practice, he served as engineer with the public works department of the Dominican Republic (till 1923) and the New Jersey Highway Dept. (1923–31). At one time he was engineer for seventeen townships in Bergen County, N.J., and at the time of his death he was consultant to Morris County Freeholders in that state.

An AWWA member since 1936, he also belonged to ASCE, National Society of Professional Engineers, New Jersey Municipal Engineers Assn. (past-president), New Jersey Sewage Works Assn., and North Jersey Water Conference (past vice-chairman).

George Smolak, research manager, Pipe Dept., Johns-Manville Research Center, Manville, N.J., died in April 1959 at the age of 59. Born in New York, he was graduated from the University of Idaho in 1922 as a mining engineer and received a master's degree there in 1924. After working as a research chemist for General Electric Co., he came to Johns-Manville in 1927. An AWWA member since 1951, he also was associated with ACS, Electrochemical Society, and American Assn. for the Advancement of Science.

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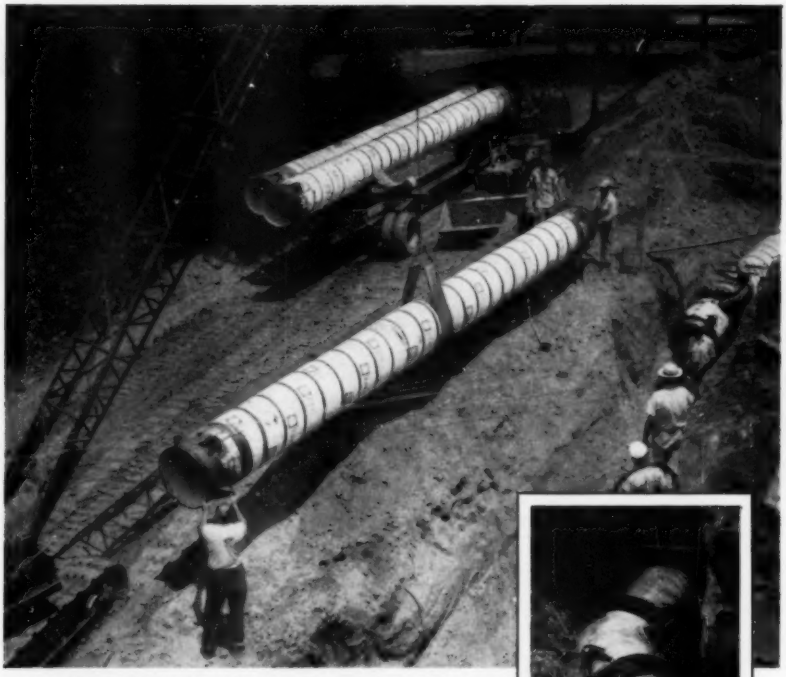

Atlanta, Georgia: This 8200′ extension of the existing water supply main system was laid by Arthur Pew Construction Co. of Atlanta. The line is Dresser-Coupled throughout.

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Ring balance meters are featured in a new 8-page, illustrated bulletin. Among the features of the instrument discussed are its applications to flow metering, measurement of suspended solids, and proportional chemical feeding. Bulletin MSP-160 is available by writing the Controls Div., Hagan Chemicals & Controls, Inc., Box 1346, Pittsburgh 30, Pa.

Check valves are described in an 8-page, two-color booklet that contains detailed drawings, dimension tables, and sample specifications for use of the automatically operating controls. Copies of Bulletin S-2-B may be obtained from Golden-Anderson Valve Specialty Co., 1221 Ridge Ave., Pittsburgh 33, Pa.

Plastic fittings for polyethelene pipe are the subject of a 4-page, two-color catalog. Complete with illustrations and specific data on use of the fittings, the publication is available from Industrial Plastic Fittings Div., R&K Plastic Industries Co., 11 W. Pennsylvania Ave., Towson, Md.

Centrifugal pumps, specially designed for air-conditioning systems, lawn-sprinkling systems, and small cooling towers, are described in a 4-page catalog that utilizes outline dimensions, design data, and performance curves. Catalog D-101 may be obtained from the Pump Div., C. H. Wheeler Mfg. Co., 19th & Lehigh Ave., Philadelphia 32, Pa.

Valves are illustrated and described on a two-color, 12 × 18-in. wall chart. The reference data on relief valves, safety devices, and pressure regulators are available by requesting Wall Chart No. 59 from A. W. Cash Valve Mfg. Corp., Box 191, Decatur, Ill.

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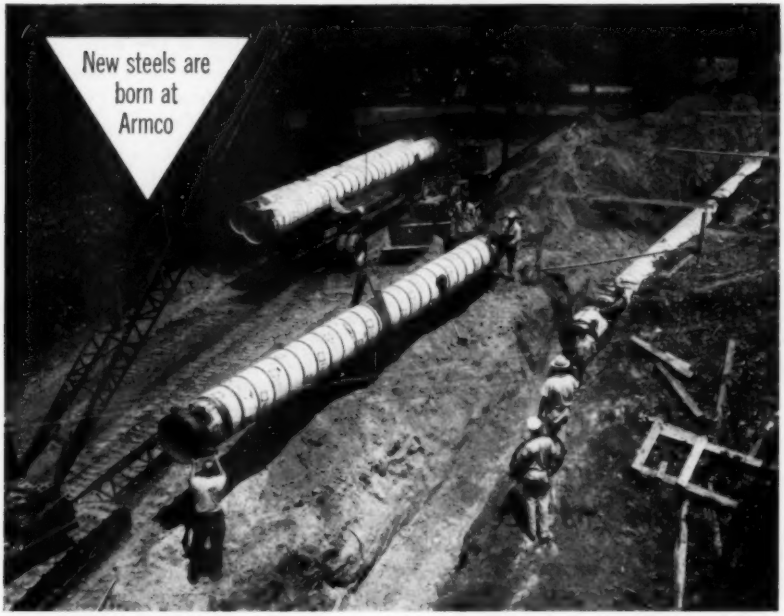

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Dresser Mfg. Div.
E. H. Wachs Co.

Covers, Vault:
Ford Meter Box Co.
E. H. Wachs Co.

Desalinization Plants:
Emhart Mfg. Co., Maxim Div.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engineers and Chemists:
(See Professional Services)

Evaporating Equipment:
Emhart Mfg. Co., Maxim Div.

Feedwater Treatment:
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
Dicalite Div.
General Filter Co.
Johns-Manville Corp.
Monterey Sand Co.
Northern Gravel Co.
Permutit Co.
Stuart Corp.

Filters, incl. Feedwater:
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Permutit Co.
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Cochrane Corp.
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Morgan Steel Products, Inc.
Southern Pipe & Casing Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.
Olin Mathieson Chemical Corp.
Tennessee Corp.

Fluoride Feeders:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
B-I-F Industries, Inc.—Builders
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Mueller Co.
Southern Pipe & Casing Co.

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Photovolt Corp.
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Chemical Process Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe & Casing Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

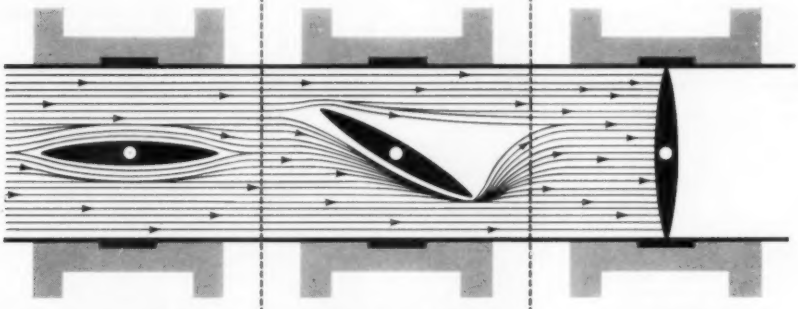
Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.

BUTTERFLY VALVE FACT FILE

3 jobs a valve should do

The three functions of a valve are these ...
1 ... to provide free flow when open,
2 ... to control flow in intermediate positions,
3 ... to shut off completely when closed.
Not all valves can do *all* these tasks with equal efficiency, and in many cases, the installation of two valves in series has become an expensive and awkward compromise. Let's see how butterfly valves (as built by Henry Pratt) meet the three vital essentials:



FREE FLOW WHEN OPEN

A lens shaped, streamlined valve disc offers the least possible resistance to flow. Actual head loss factor (K) in a fully opened low pressure valve is equal to 0.263, or only 60% of the loss through a 45° pipe elbow.

EFFECTIVE FLOW CONTROL

Flow characteristics of a butterfly valve are similar to those of a V-port plug valve, but with only ⅓ the head loss in the open position. Butterfly valves have a minimum to maximum controllable flow ratio (rangeability) of 25 to 1.

TIGHT CLOSURE

Closing smoothly into the seat, the disc squeezes into the rubber to obtain closure. Heavy rubber seat minimizes wear, assuring **continued** tight shutoff; corrosion resistant disc edge means valve will operate easily even after being closed for years.

Henry Pratt Low Pressure Rubber Seat Butterfly Valves are suitable for operating temperatures ranging from −20°F. to 190°F., and shutoff pressures ranging from vacuum to 50 psi.

HENRY PRATT RUBBER SEAT Butterfly Valves

If you would like more technical data on butterfly valves, write for the Henry Pratt Manual of Rubber Seat Butterfly Valves B-2C.

HENRY PRATT COMPANY, 2222 S. HALSTED ST., CHICAGO 8, ILL. • REPRESENTATIVES IN PRINCIPAL CITIES

Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.
Hays Mfg. Co.
Hersey Mfg. Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Filtration Plant, Pumping Station, Transmission Line:
B-I-F Industries, Inc.—Builders
Foster Eng. Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Burgess-Manning Co., Penn Instruments Div.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Southern Pipe & Casing Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
Morgan Steel Products, Inc.
Orangeburg Mfg. Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe & Casing Co.

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Southern Pipe & Casing Co.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
E. H. Wachs Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
National Aluminate Corp.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
National Aluminate Corp.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
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Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.

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. . . the better your reasons for

giving them to

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If you're puzzled over which pumps to use for water works, municipal or industrial power plant service, drainage, irrigation or flood control, see C. H. Wheeler. Your representative can help you even if you need capacities exceeding 220,000 gpm and heads of 75 feet. He'll give you expert advice on pump design and construction, and station arrangement suggestions you'll find helpful.

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Graver Tank & Mfg. Co.
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Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Inc.

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
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Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
W. S. Rockwell Co.
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Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
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B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
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James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Reconditioning and Formation Testing:
Halliburton Oil Well Cementing Co.
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1957 AWWA Directory.

KENNEDY VALVE has a complete line of A.W.W.A. Standard Gate Valves . . .

. . . that conform to A.W.W.A. specifications in all respects

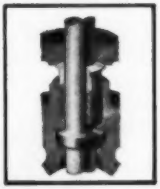
FIG. 58
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Bell Ends

FIG. 571X
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

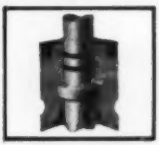
FIG. 566
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

Construction features . . .



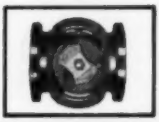
Conventional stuffing box

with adjustable gland has ample space for packing that conforms to Federal specification HH-P-106c. The bottom face of the stuffing box flange is faced smooth to form bearing surface for stem thrust collar.



O-Ring seals

once installed no adjustment of any kind is required. The top O-Ring is the dirt seal and the bottom O-Ring is the pressure seal.



Operating nut

is Higher Strength Cast Iron. The base flange, with arrow indicating direction to open, is shaped to permit access from ground surface to adjust gland nuts with an extension socket wrench.

KENNEDY A.W.W.A. Standard gate valves are designed specifically for use in water works systems. Conforming to A.W.W.A. Specifications, in several particulars these valves exceed these standards of strength and refinements of design.

While A.W.W.A. Specifications cover only bell end and flanged end non-rising stem valves, the KENNEDY line also includes outside-screw-and-yoke valves and a wide variety of pipe connections including: Bell Ends, Flanged Ends, Mechanical Joint Ends, Universal Pipe Ends, Asbestos Cement Pipe Ends, Screwed Ends, Ring-Tite Pipe Ends and Spigot Ends.

In addition to standard features, KENNEDY A.W.W.A. Valves have reduction gearing, gear cases, by-passes; indicators and rollers, tracks and scrapers available on 16" and larger sizes. Gearing is always furnished on 30" and larger valves.

KENNEDY VALVE MFG. CO.
ELMIRA, NEW YORK
VALVES
FIRE HYDRANTS

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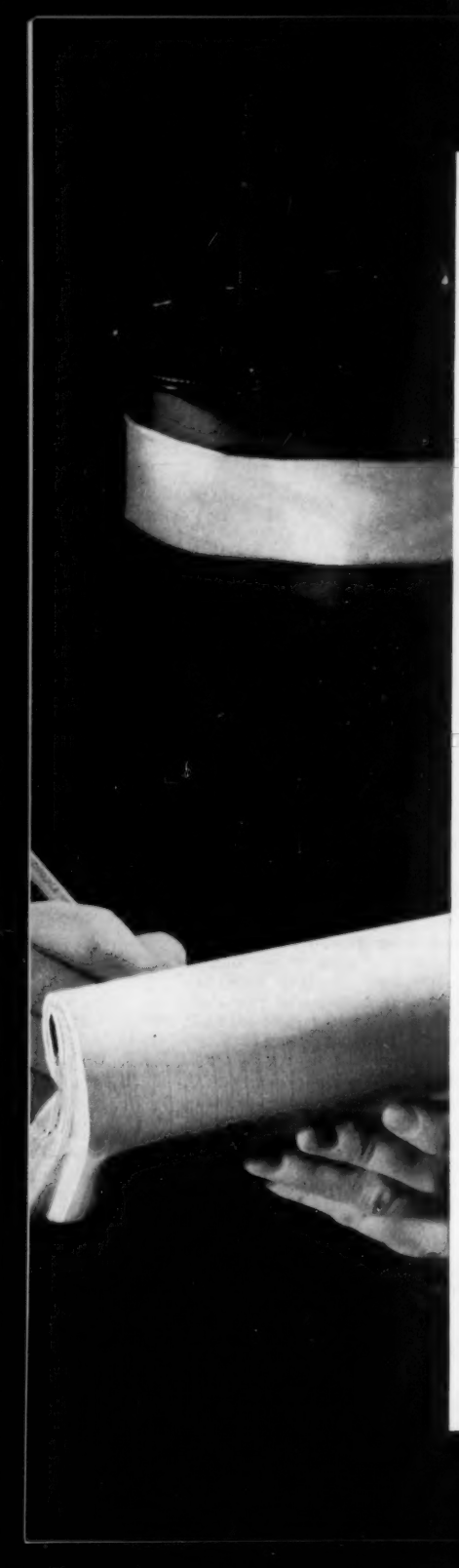

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